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To promote inter-disciplinary research in the field of agriculture and provide a forum for expressing views on policies and programmes relating to agricultural development

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Growth of Indian mustard [*Brassica juncea* (L.)] as influenced by nitrogen and its split application in arid Western Rajasthan

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ABSTRACT

A filed experiment was conducted during winter, 2002-03 and 2003-04 to find out the effect of nitrogen and its split application on growth and yield of Indian mustard [Brassica juncea (L.)] Czernj. & Cosson]. Application of increasing levels of nitrogen from 40 to 100 kg ha-1 significantly enhanced plant height,dry meter accumulation per matter row length, and primary and secondary branches/plant at harvest and leaf area per plant at reproductive stage. Further, application of nitrogen 1/3 as basal + 1/3 at 1st irrigation + 1/3 at 2nd irrigation being statistically at par with ½ at basal + ¼ 1st at 1st irrigation + 1/4 at 2nd irrigation brought a substantial improvement in plant height, dry matter accumulation per metre row length, and primary and secondary branches /plant at harvest and at flowering compared to two equal splits viz., ½ at basal + ½ at 1st irrigation, DAP basal + ½ of rest at 1st irrigation + DAP basal + ½ of rest at 1st irrigation + ½ of rest at 2nd irrigation and 100 percent basal.

Key words : Indian mustard, nitrogen, split application, growth yield.

Mustard is an important oilseed crop of India and stands next only to groundnut in terms of both area and production. However, its productivity is low due to poor soil conditions and inadequate use of key inputs like fertilizers. Among plant nutrients, nitrogen is the most important and urea is the most widely used source of nitrogen by farmers all over the world. Efficiency of nitrogen use by most of the crops ranges from 20-60 per cent and commonly averages around 50 per cent (Aulakh et al., 1992). Low recovery of applied nitrogen by crops raises questions on the fate of the nitrogen that losts from soil-plant-system through runoff, leaching, denitrification and ammonia volatilization or made unavailable to the plant through biological immobilization. The soil of western Rajasthan is deficient in organic matter, nitrogen and phosphorus content, and requires supply of these nutrients, for sustaining crop production. Besides the amount, particularly of nitrogen, the time of nitrogen application also influences the growth of mustard especially in light textured soils and high temperature. Hence, the present investigation was undertaken to find out the effect of nitrogen levels and its split application on growth of Indian mustard.

MATERIALS AND METHODS

The experiment was conducted at College of Agriculture, Bikaner during winter, 2002-03 and 2003-04. Soil was a loamy sand and had a pH of 8.2. It was low in organic carbon (0.09%), available nitrogen (113.1 kg/ha) and available phosphorus (12.01 kg/ha) and medium in potassium (200.0 kg/ha). The treatments comprised five levels of nitrogen (40, 60, 80, 100 and 120 kg/ha) as main plot treatments and five split applications of nitrogen (100 per cent basal, ½ at basal + ½ at 1st irrigation, 1/3 as basal +1/3 at 1st irrigation + 1/3 at 11nd irrigation, ½ at basal + ¼ at 1st irrigation + ¼ at 11nd irrigation and DAP basal + ½ of rest at 1st irrigation + ½ of rest at 11nd irrigation) as sub pot treatments and were laid out in a split plot design with three replications. Nitrogen, for different treatments, was applied through urea after adjusting the nitrogen (13.7 kg N) supplied through DAP (applied for 35 kg P_2O_5). The calculated quantity or urea for different treatments was applied basal and remaining nitrogen was given at 1st and 11nd irrigation, as per treatments at 30 and 60 days after sowing, respectively. Indian mustard variety Bio-902 (Pusa Jaikisan) was sown at 30 cm row spacing using 4 kg seed/ha on 29 and 27 October in 2002 and 2003, respectively.

RESULTS AND DISCUSSION

Effect of nitrogen levels

Application of increasing levels of nitrogen from 40 to 100 kg/ha significantly enhanced the plant height, dry matter accumulation per meter row length, leaf area and primary branches per plant at 45 and 90 DAS and at harvest and secondary branches per plant of mustard at 90 DAS and at harvest. The effect of different levels of nitrogen from 40 to 100 kg N/ha was significant to each other; however, the effect of 120 kg N/ha was found to be at par with 100 kg N/ha (Tables 1 and 3). The magnitude of increase under 100 kg N/ha were 48.16, 26.25 and 11.21 per cent in plant height at 45 DAS, 35.90, 20.16 and 8.84 per cent in plant height at 90 DAS, 39.59, 21.79 and 9.47 per cent in plant height at harvest, 27.59, 15.65 and 6.24 per cent in dry matter accumulation per meter row length at 45 DAS, 45.82, 20.15 and 7.85 per cent in dry matter accumulation per meter row length at 90 DAS, 55.69, 24.04 and 9.29 per cent in dry matter accumulation per meter row length at harvest, 27.60, 15.69 and 6.26 per cent in leaf area per plant at 45 DAS, 45.92, 20.14 and 7.83 per cent in leaf area per plant at 90 DAS, 55.67, 24.05 and 9.29 per cent in leaf area per plant at harvest, 49.19, 22.51 and 8.18 per cent in primary branches per plant at 45 DAS, per cent in primary branches per plant at 90 DAS, per cent in primary branches per plant at harvest, 55.05, 27.22 and 10.32 per cent in secondary branches per plant at 90 DAS and 44.72, 23.88 and 9.48 per cent in secondary branches per plant at harvest over 40, 60 and 80 kg N/ha, respectively.

In general, the overall improvement in growth of mustard with increased nitrogen could be ascribed to its pivotal role in several physiological and biochemical processes which are of vital importance for growth and development of plant. The increased N supply increased the leaf area which might have accelerated the photosynthetic rate, thereby, increasing the supply of carbohydrates to the plant (Khanpura *et al.*, 1993) which might have been attributed to significantly higher growth. Beneficial effect of nitrogen addition on growth parqameters have also been reported in mustard by Shukla *et al.* (2001), Garg *et al.* (2001), Kumar *et al.* (2001) and Tripathi *et al.* (2002) at Kanpur in Indian Mustard.

Effect of Split Application of Nitrogen

Further an application of nitrogen as full basal significantly increased the plant height, dry matter accumulation per metre row length, leaf area and primary branches per plant of mustard at 45 DAS over different split applications in mustard. Application of nitrogen as 100% basal significantly increased in 11.19, 26.48, 12.46 and 40.03 per cent plant height, 10.0, 18.72, 10.24 and 29.25 per cent dry matter accumulation per metre row length, 10.12, 18.75, 10.24 and 29.25 per cent leaf area per plant and 25.15, 46.15, 27.44 and 53.67 per cent primary branches per plant at 45 DAS over nitrogen splitting ½ as basal + ½ at Ist irrigation, 1/3 as basal + 1/3 at Ist irrigation + 1/3 at IInd irrigation, ½ at basal + ¼ at Ist irrigation + ¼ at IInd irrigation and DAP basal + ½ of rest at Ist irrigation + ½ of rest at IInd irrigation, respectively.

However, nitrogen applied in three equal splits 1/3 at sowing + 1/3 at Ist irrigation + 1/3 at IInd irrigation being statistically equal with ½ at basal + ¼ at Ist irrigation + ¼ at IInd irrigation produced significantly higher plant height, dry matter accumulation per meter row length, leaf area and primary and secondary branches per plant of mustard at 90 DAS and at harvest (Tables 1 and 2). The significant increase due to application of nitrogen ½ at basal + ½ at Ist irrigation, 1/3 at basal + 1/3 at Ist irrigation + 1/3 at IInd irrigation, ½ at basal + 1/4 at Ist irrigation + ¼ at IInd irrigation and DAP basal + ½ of rest at Ist irrigation + ½ of rest at IInd irrigation was 10.75, 21.83, 23.03 and 9.42 per cent in plant height at 90 DAS, 12.65, 29.98, 25.27 and 10.86 per cent in plant height at harvest, 8.84, 16.15, 15.82 and 7.48 per cent in dry matter accumulation per metre row length at 90 DAS, 23.33, 35.93, 32.57 and 24.73 per cent in dry matter accumulation per meter row length at harvest, 8.95, 16.21, 150.93 and 7.57 per cent in leaf area at 90 DAS, 23.32, 35.92, 32.56 and 24.72 per cent in leaf area at harvest, 11.56, 20.16, 20.16 and 10.75 per cent in primary branches per plant at 90 DAS, 12.76, 23.67 and 13.83 per cent in primary branches per plant at harvest, 14.11, 44.18, 39.44 and 13.25 per cent in secondary branches per plant at 90 DAS and 22.92, 38.24, 34.63 and 17.11 per cent in secondary branches per plant of mustard at harvest respectively, over full basal. Further, DAP basal + ½ of rest at Ist irrigation + ½ of rest at IInd irrigation being statistically non-significant to two equal split of ½ at sowing at Ist irrigation recorded significantly higher dry matter accumulation at 90 DAS over full basal.

Leaching and volatilization losses of nitrogen particularly under loamy sand soil result in low availability of nitrogen at basal application which mighty be due do unable to fulfill the supply of nitrogen at critical growth stage of plants. Hence, the marked improvement in growth parameters, due to split application of nitrogen could be ascribed to rational utilization of N at its critical growth stages which play a

Table 1. Effect of nitrogen and its split application on growth and yield of Indian mustard (average of 2 years)

Treatments	Plant height (cm) at harvest	Dry matter accumulation (g per metre row length) harvest	Leaf are/plant (dm^2) 90 DAS	Primary branches/ plant at harvest	Secondary branches/ plant at harvest
Nitrogen levels (kg/ha)					
40	116.0	133.1	93.0	3.4	9.6
60	133.0	167.1	113.0	4.0	11.1
80	148.0	189.7	125.9	4.4	12.6
100	162.0	207.3	135.8	4.7	13.8
120	163.3	211.9	138.5	4.8	13.9
CD (P=0.05)	8.9	9.1	5.7	0.2	0.7
Slit application of N					
Basal 100%	124.8	147.5	110.5	3.7	9.9
½ Basal + ½ at Ist irrigation	140.6	181.9	120.4	4.2	12.2
1/3 Basal + 1/3 at Ist irrigation + 1/3 at IInd irrigation	162.2	200.5	128.4	4.6	13.8
½ Basal + ¼ at Ist irrigation + ¼ at IInd irrigation	156.4	195.5	128.1	4.6	13.4
DAP basal1 + ½ of rest2 at Ist irrigation + ½ of rest at IInd irrigation	138.4	183.9	118.8	4.2	11.7
CD (P=0.05)	6.7	7.8	4.5	0.2	0.6

potential role in modifying plant environment vis-avis better growth and development of the crop. Similar findings were also reported by Mohapatra (1993) in mustard, Ahmad et al. (1999) at Pakistan in mustard, Behrens et al. (2001) and Tamagno et al. (2001) at Argentina in rapeseed.

Interaction effect of nitrogen levels and its split application

A significant interaction was recorded between levels and split application of N for dry matter production per metre row length at harvest (Table 2). As the level of nitrogen increased from 40 kg to 120 kg N ha-1, a positive increase in dry matter accumulated per metre row length was recorded with splitting of nitrogen at different doses.

Application of nitrogen as 100 per cent basal and DAP basal + ½ of rest at Ist irrigation + ½ of rest at IInd irrigation increased dry matter accumulation significantly up to 80 kg N ha-1 only, but nitrogen applied in two equals splits ½ as basal + ½ at Ist irrigation increased dry matter accumulation up to 100 kg N ha-1. Whereas, under 1/3 as basal + 1/3 at Ist irrigation + 1/3 at IInd irrigation and ½ at basal + ¼ at Ist irrigation + ¼ at IInd irrigation, dry matter per metre row length increased significantly up to 120 kg N/ha.

The highest dry matter production per metre row length was recorded with the application of 120 kg N/ha in three splits i.e. at 1/3 as basal + 1/3 at Ist irrigation + 1/3 at IInd irrigation.

Table 2. Interaction effect of nitrogen levels, and their split application on dry matter accumulation in mustard (average of 2 years

Treatments	Dry matter per metre row length (g)				
	N40	N60	N80	N100	N120
Basal 100%	91.80	132.84	161.56	174.90	176.41
½ Basal + ½ at Ist irrigation	139.87	167.19	184.08	215.69	202.74
1/3 Basal + 1/3 at Ist irrigation + 1/3 at IInd irrigation	145.35	173.23	198.70	228.70	256.63
½ Basal + ¼ at Ist irrigation + ¼ at IInd irrigation	147.49	179.72	195.83	218.83	236.23
DAP basal + ½ of rest at Ist irrigation + ½ of rest at IInd irrigation	141.43	182.85	208.54	199.19	187.89
SEm ±	6.265				
CD (p=0.05)	17.63				

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Productivity of wheat and soil organic carbon status under integrated use of organic and inorganic fertilizers

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ABSTRACT

A field experiment was conducted during 2004-05 to 2008-09 at New Delhi to find out the suitable combination of organic manure, biofertilizer and chemical fertilizer on wheat yield and soil organic carbon status in rice-wheat cropping system. The experiment consists 17 treatments combinations of three doses of chemical fertilizer (40, 80 and 120 kg N/ha), two biofertilizers (*Azotobacter* and BGA) and one organic manure (FYM). Results revealed that grain yield of wheat increased significantly due to the application of Azotobacter and FYM or in combination with chemical fertilizer. The increase in grain yield due to the combined application of 2 organic inputs was higher as compared to single input. The application of 3 organic inputs with N40 and N80 gave yield enhancement which was higher than 30 kg N/ha. The treatment having absolute control showed a decline in soil organic carbon (SOC). SOC content in soil at crop harvest was significantly increased due to integrated application of biofertilizers and FYM as compared to chemical fertilizer alone. Integrated application of single biofertilizers and FYM maintained the SOC level while combined application of 2 or 3 biofertilizer / FYM enhanced the SOC level over the years.

Key words : Wheat, biofertilizers, soil quality, soil organic carbon, integrated nutrient management

Rice-wheat is the major cropping system covering 12.5 million ha in northern Indo-Gangatic plains and contributes about 25% of total food grain production in India. Yields of. wheat and rice have been considerably improved with increased use of fertilizer and improved management techniques. However, this cropping system has shown the symptoms of resource degradation (Hobbs, 1994) and there are indication of stagnation or even decline in factor productivity of this cropping system due to the over mining and losses of nutrients from soil varying from 600 to 700 kg/ha every year against the application of 400 kg NPK/ha. The integrated nutrient management (INM) technique of soil fertility management is one of the critical components to enhance and sustain productivity and soil fertility. The INM technology through proper dose of chemical fertilizer and organic material can assure optimum crop yield, sustain soil nutrient reserve, yet not environmentally degrading in the long run is the need of the time. Locally available organic sources like animal manure (farm yard manure), biofertilizers, straw and crop residues have been reported to contribute in enhancing soil fertility and productivity. Options like green manuring is not popular because it does not offer any ready cash return. An increase in soil organic matter was reported to improve soil quality by acting as revolving nutrient bank account and also as an agent to improve soil structure, maintain tilth and retain moisture. Many workers have suggested that long-term application of inorganic fertilizer may lead to poor levels of soil organic matter and lower yield (Akram *et al.*, 2007). However, available informations are conflicting and uncertainties still remain about the influences of inorganic fertilizers on soil quality and production capacity. Some studies have shown that continued use of inorganic fertilizers may result in diminishing soil quality and productive capacity (Doran *et al.*, 1996; Nel *et al.*, 1996; Bhaduri *et al.*, 2002; Manna *et al.*, 2005). Others have indicated both positive and negative effects (Johnston, 1991; Regmi *et al*, 2002) and no noticeable changes (Aref and Wandre, 1998) in soil quality and productive capacity. With such background an experiment was conducted to assess the effect of inorganic fertilizers and combinations of both nutrients sources on soil quality and productivity of wheat.

MATERIALS AND METHODS

A field experiment was conducted during five consecutive Rabi seasons from 2004-05 to 2008-09 at Research farm of Indian Agricultural Research Institute, New Delhi, situated at a latitude of 28° 40'N and longitude of 77° 12' E, altitude of 228.6 m above the mean sea level. The mean annual rainfall of Delhi is 650 mm and more than 80% generally occurs during the south-west monsoon season (July-September) with mean annual evaporation 850 mm. The soils of the experimental field was sandy clay loam and its initial soil sample had 243 kg/ha alkaline permanganate oxidizable N, 18.0 kg/ha available P, 281 kg/ha 1N ammonium acetate exchangeable K and 0.38% organic C. The pH of the soil was 7.4 (1: 2.5 soil and water ratio). Composite soil sample taken before the start of experiment in November 2004 contained a microbial population (CFU/ gm soil) of 73 x 103 Actinomycetes, 196 x 103 Bacteria, 17 x 103 Fungi and 4 x 103 BGA. The experimental area was under rice-wheat cropping system during last ten years. In the experiment on wheat, 17 treatments combinations having three doses of chemical fertilizer (40, 80 and 120 kg N/ha), two biofertilizers (*Azotobacter* and BGA) and one organic manure (FYM) were applied in different combinations. *Azotobacter* was applied @ 500 g / ha through seed treatment at the time of sowing. Multani mitti based blue green algae (BGA) having composite culture of four species viz., Anabaena sp., Nostoc sp., Tolypothrix sp. and Aulosira sp. was applied @ 1.5 kg/ha as top dressing 3 days after sowing. Dry biomass of BGA contained 4.4% N, 0.89% P, 4.9% K, iron 712 ppm, zinc 76 ppm, manganese 161 ppm and copper 23 ppm. Urea was applied to supply chemical nitrogen as per treatment. Recommended dose of P and K (26.2 kg P/ha as SSP and 33 kg K/ha as MOP) were broadcasted at the time of sowing in all the treatments except treatment having absolute control ($N_0P_0K_0$). Wheat variety 'HD 2687' was taken and sown under 'no tillage' with no-till seed drill and five irrigations and weed management practices were taken as per recommended practice.

Soil samples were collected before beginning of the experiment and after harvest of wheat crop from a depth of 0-15 cm and were analyzed for SOC. Rice crop was taken in the same field during kharif season using recommended dose of chemical fertilizers and organic manure (75:25).

RESULTS AND DISCUSSION

Wheat yield

Grain yield of wheat increased significantly due to the application of biofertilizers or organic manure alone or in combination with chemical fertilizer (Table 1). An increase of 5.2, 12.3 and 15.1% in grain yield was recorded due to single application BGA, *Azotobacter* and FYM with 40 kg N/ha, respectively. The corresponding increase due to same organic inputs with 80 kg N/ha was recorded 1.4, 5.7 and 9.9%, which indicated poor response of biofertilizers at higher dose of chemical fertilizers. The increase in grain yield due to the combined application of 2 organic inputs was higher as compared to single input and the increase ranged between 20.2 to 31.3 % and 9.6 to 9.9% with N40 and N80, respectively. However the increase in yield with 3 inputs with N40 and N80 was 36.9 and 20.9 % respectively. The comparison of yield increase due to N120 and N80 with 3 organic input applications with N40 and N80 indicated that the 3 organic inputs gave yield enhancement which was higher than 30 kg N/ha. A combination of both inorganic and organic fertilizers was described as the answer for sustainability (Zeleke *et al.*, 2004). Combination of organic sources (FYM/green manure) with chemical fertilizers (25:75) was reported to produce more grains compared to fertilizers alone in the rice-wheat system in India (Yadav *et al.*, 1992). Use of bio-solids for complementing chemical fertilizers was reported to enhance the system sustainability and escape to environmental degradation threat in the long run (Recheig and Mackinnon, 1997).

Table 1. Effect of different treatments on grain yield of wheat during 2004-2009

Treatments	Grain yield of wheat (t/ha)					
	2004-05	2005-06	2006-07	2007-08	2008-09	Mean
N_{40}	2.65	2.47	2.54	2.34	2.41	2.52
N_{40} +*Azotobacter*(A)	2.85	2.87	2.85	2.72	2.85	2.83
N_{40}+BGA (B)	2.78	2.78	2.56	2.65	2.48	2.65
N_{40}+FYM (F)	2.92	2.92	2.76	3.02	2.89	2.90
N_{40} +A+B	3.04	3.04	2.87	3.21	3.00	3.03
N_{40}+A+F	3.24	3.24	3.02	3.49	3.54	3.31
N_{40}+B+F	3.10	3.10	2.68	3.50	3.53	3.18
N_{40}+A+B+F	3.35	3.35	3.23	3.65	3.69	3.45
N_{80}	3.45	3.45	3.34	3.75	3.67	3.53
N_{80}+A	3.65	3.65	3.54	3.88	3.92	3.73
N_{80}+B	3.59	3.59	3.45	3.67	3.61	3.58
N_{80}+F	3.78	3.78	3.58	3.86	3.91	3.78
N_{80}+A+B	3.80	3.80	3.65	3.99	3.94	3.84
N_{80}+A+F	3.82	3.82	3.68	4.02	3.99	3.87
N_{80}+B+F	3.89	3.89	3.72	3.97	3.89	3.87
N_{80}+A+B+F	4.35	4.05	4.14	4.36	4.45	4.27
N_{120}	4.15	4.10	4.07	4.16	4.21	4.14
N_0 P_0K_0 (control)	1.85	1.85	1.32	1.85	1.85	1.74
C.D. (P=0.05)	0.26	0.31	0.23	0.27	0.26	0.28

Rate of application/ha: Azotobacter 0.5 kg; BGA 1.5 kg; FYM 5.0 t.

Table 2. Effect of different treatments on organic carbon content in soil at wheat harvest

Treatments	Soil organic carbon content (%)				
	2004-05	2005-06	2006-07	2007-08	2008-09
N_{40}	0.35	0.33	0.32	0.33	0.35
N_{40} +*Azotobacter*(A)	0.37	0.38	0.38	0.39	0.41
N_{40}+BGA (B)	0.37	0.38	0.39	0.40	0.42
N_{40}+FYM (F)	0.39	0.41	0.42	0.42	0.43
N_{40} +A+B	0.41	0.42	0.43	0.42	0.44
N_{40}+A+F	0.43	0.43	0.45	0.44	0.45
N_{40}+B+F	0.42	0.44	0.46	0.47	0.46
N_{40}+A+B+F	0.44	0.46	0.48	0.50	0.52
N_{80}	0.37	0.35	0.36	0.34	0.35
N_{80}+A	0.40	0.42	0.41	0.43	0.44
N_{80}+B	0.39	0.40	0.40	0.44	0.45
N_{80}+F	0.41	0.44	0.46	0.45	0.48
N_{80}+A+B	0.42	0.44	0.47	0.47	0.49
N_{80}+A+F	0.43	0.45	0.48	0.49	0.49
N_{80}+B+F	0.45	0.47	0.47	0.48	0.50
N_{80}+A+B+F	0.47	0.48	0.49	0.51	0.53
N_{120}	0.36	0.34	0.35	0.34	0.34
N_0 P_0K_0 (control)	0.34	0.36	0.35	0.32	0.30
C.D. (P=0.05)	0.03	0.04	0.04	0.06	0.05

Soil organic carbon

Soil organic carbon (SOC) content in soil at crop harvest was found to be significantly increased due to the integrated application of biofertilizers and FYM as compared to chemical fertilizer alone (Table 2). The same trend was observed in all the years. Integrated application of single biofertilizers and FYM maintained the SOC level while combined application of 2 or 3 biofertilizer/FYM enhanced the SOC level over the years. Application of organic waste at a rate of 10 Mg/ha was reported to increased soil organic matter without risk of N leaching (Korboulewsky *et al.*, 2002). Bhaduri *et al.* (2002) reported a decline in soil organic carbon (SOC) in control treatment while balanced fertilization with NPK maintained the SOC. Studies have shown that increase in SOC levels is directly linked to the amount and quantity of organic residues return to the soils (Rasmussen *et al.*, 1980). In addition to manuring and also fertilization (Hartwig and Ammon, 2002), cropping sequence (Kuo *et al.* 1997) can also affect the SOC stocks. Further, soil aggregation dynamics also influence SOC sequestration and cycling (Tisdall and Oades, 1982).

Above study indicates that the integrated application of *Azotobacter* and FYM with chemical fertilizers gave significantly higher grain yield of wheat as compared to chemical fertilizer alone at N40 and N80. However, application of BGA did not have significant effect on grain yield of wheat. Integrated use of organic (biofertilizers and organic manure) and inorganic (chemical fertilizer) inputs maintained the organic carbon content of soil on long term basis and thus indicated for its potential and utility for a sustainable crop production and soil fertility in rice-wheat system.

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Heterotic potential of basmati type restores for milling and physico-chemical quality in rice (*Oryza sativa* L.)

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ABSTRACT

Three CMS lines, namely IR 68888A, IR 68891A and IR 58025A were crossed with their respective basmati type restorers during kharif, 2006. The resultant 35 crosses were evaluated for milling and physico-chemical quality character using checks as Taraori Basmati (an export quality rice), and grain yield was compared with Pusa Basmati-1 (a semi-dwarf high yielding variety) during kharif, 2007. Out of 35, three hybrids viz., IR 58025A x PB-6-12-55-5, IR 6888A x PB-3-17-57-1 and IR 6888A x PB-5-14-50-1 were found superior over Taraori basmati for seven, six and five milling and physico-chemical traits, respectively, which also showed superiority over Pusa Basmati-1 for grain yield plant-1. Out of which, one hybrid IR 68888A x PB-3-17-57-1 exhibited higher out crossing potential (34.40%) which would be uuseful to reduce cost of hybrid seed when used as commercially.

Key words : Heterosis, basmati rice, milling and physico-chemical quality traits.

Basmati rices command a very high premium in domestic as well as international markets due to their long slender superfine grains, pleasant aroma, soft texture and extreme grain elongation with least breadth wise expansion on cooking, our country earns more foreign currency about Rs. 3200 crores annually by exporting basmati rices. Increasing demand of basmati rices by most of the countries provide opportunity to expand rice export markets in world trade (Sing et al., 2000). However, our country has also exported non-basmati rices due to insufficient production of quality rices. Hence there is an urgent need to increase productivity of quality rices without sacrificing their quality characteristics. In this direction, hybrid technology is the best approach used to increase Productivity of most of the crops. Out crossing potential of CMS lines is another important aspect of hybrid breeding programme which would help to produce huge quantity of hybrid seed with minimum cost. Keeping in view, the present study has been planned to develop high quality rice by using basmati type parental lines, and evaluate them with standard checks for milling, physico-chemical quality traits and grain yield plant-1, and assessment of ourcrossing potential of CMS lines with their respective restorers was also including in this study.

MATERIALS AND METHODS

Three CMS lines viz., IR 68888A, IR 68891A and IR 58025 A were crossed with basmati type restorers at the Agriculture Research Farm of Amar Singh (P.G.) College, Lakhaoti, Bulandhshahr during kharif 2006. The resultants 25 hybrids were evaluated alongwith Taraori Basmati (an export quality rice) and Pusa Basmati^{-1} (a semi-dwarf high yielding variety) for milling, physico-chemical quality traits and grain yield plant^{-1}, respectively at the same research farm during kharif, 2007. A row of 3 m length of each entry per replication was planted with a spacing of 20 x 20 cm using as a single seedling per hill. All the recommended practices were adopted to raise a good and healthy crop. All the data of milling and physico-chemical quality characters were measured from bulk seeds of ten randomly selected plants per replication, while grain yield plant-1 was observed individually from randomly selected plants. The head rice recovery was measured from whole kernels of milled rice. Grain size and shape like kernel length, kernel breadth were measured from whole milled kernels using dial micrometer (Mututoya), and L/B ratio was computed as ratio kernel length to kernel breadth. Kernel elongation was measured from cooked kernels with the help of photographic enlarger and elongation was calculated as ratio of average length of cooked kernels to average length of raw kernels. Important cooking quality characters like amylase content, gel consistency, alkali spreading value, volume expansion and water uptake number were measured as per standard procedures of Sadasivum and Manikkam (1992), Cagampeng et al. (1973), Little et al. (1958); and Beachell and Stansel (1963), respectively. Out crossing of CMS lines were assessed by planting of CMS lines with their effective restorers in a crossing block with the ratio of 4:2 (A:R lines). At the maturity, all the plants of CMS lines were used to count spikelet fertility, and outcrossing potential was computed as proportion of fully developed grains to total number of spikelets.

RESULTS AND DISCUSSION

The range of standard heteroris and number of crosses showing significant heterosis are presented in Table 1. The head rice recovery is important milling quality character, its higher values (.65%) are much preferred by the millers and trader. Out of 25, 23 hybrids exhibited significant positive standard heterosis, whereas three promising hybrids were identified milling, physico-chemical traits, and grain yield plant-1 are presented in Table 2. Long grained (.7.75% mm) aromatic varieties are much liked by the consumers everywhere. Many long grains hybrids were identified in this study which showed significant positive standard heterosis as well as high mean values upto 8.11 mm. The mean and standard heterosis of top ten cross combinations are presented in Table 3. The kernel breadth is important grain quality character determines grain fineness, and its least value (,1.90 mm) is desirable. 9 hybrids exhibited fine grains but significant heterosis was not observed for this character. The L/B ratio is also important grain quality character determines the shape of rice grains, its higher value (.3.00) is desirable, three hybrids were identified as slender grains. The kernel elongation is very important cooking quality character, its higher value (1.8) is desirable (Latha et al., 2005) Ninteen hybrids showed high kernel elongation but significant heterosis was not observed in the hybrids. The amylose content and alkali spreading value both are important cooking quality characters, their intermediate values (20-25 and 4-5) are desirable (Vaneja and Baby, 2006), which makes rice to cook flaky, fluffy and remains soft a cooking, and 4 for alkali spreading value were observed with significant positive standard heterosis. Similar results were also reported by Yolanda and Das (1996).

Table 1. Range of standard Heterosis for different quality characters and grain yield/plant

Characters	Standard Heterosos (%) Range	SE (±)	No. of crosses with significant heterosis
Head rice recovery	-9.64-32.50	2.66	23
Kernel length	-9.65-16.55	0.41	09
Kernel breadth	-4.32-35.13	0.11	00
L/B ratio	-21.48-12.02	0.16	03
Kernel elongation	-3.79-5.34	0.07	00
Amylose content	-15.56-25.00	1.47	16
Gel consistency	-53.3-5.33	2.08	09
Alkali spreading value	-45.36-32.13	0.18	04
Volume expansion	-13.15-47.63	0.30	14
Water uptake number	-6.25-59.16	5.07	24
Grain yield plant-1	5.04-111.23	2.70	25

Table 2. Promising crosses combinations for different physico-chemical traits and grain yield/plant

Characters	Cross combinations
Head rice recovery	IR 68888A x PB-\5-14-501, IR 5025 A x PG-3-17-5-2 IR 68888 A x KCN-80152
Kernel length	IR 6888 A x Basmati Sathi, IR 5025 A X PB-3-17-52, IR 5025 A x PB - 12-55-5
L/B ratio	IR 58025 A x PB-612-55-5, IR 6 A x Hawm Kikwai, IR 5025 A x PB-418-57-6
Amylose content	IR 6888 A x PB-6-12-24-4, IR 68888 A x PB-3-17-57-1, IR 68891 A x Hawm Kikwai
Gel consistency	IR 58025 A x PB-6-12-55-5, IR 58025 A x Basmathi Sathi, IR 58025 A x Pusa Basmati-1
Alkali spreading value	IR 68888 A x PB-3-17571, IR 68888 A x PB-5-14-50-1
Volume expansion	IR 58025 A x PB-6-12-55-5, IR 68888 A x PB-6-12-24-4, IR 5025 A x Pakistani Basmati
Water uptake number	IR 68888 A x Hawm Kikwai, IR 6891 A x PB-5-14-50-1, IR 58025 A x PB-6-12-55-5
Grain yield/plant	IR 68888 A x PB-6-12-24-4, IR 6891 A x PB-5-14-50-1 IR 68891 A x PB-8-4859-2
Out crossing potential	IR 68888 A x Basmati-397, IR 58025 A x Khao Dawk Mali 105, IR 68888 A x Basmati Sathi

The water uptake number and volume expansion are also important cooking quality characters, their higher values (.250 ml & times) are desirable. The positive significant standards heterois was observed in 24 and 14 hybrids for these characters, respectively. The yield heterosis in rice hybrids ranged from 5.04-111.23%, and 25 hybrids exhibited significant positive standard positive standard heterois over Pusa Basmati-1. The out crossing potential of CMS lines ranged from 14.65-44.67% and three promising hybrids were identified for this character which would be useful to produce huge amount of hybrid seed with minimum cost. Aroma is the major component of quality rices much preferred by the consumers, but aroma was not expressed in cooked kernel during testing, this is probably due to segregation of F1 seeds into aromatic and non aromatic ones. Hence it is suggested that whole individual kernel of each plant should be used to test aroma properly, because in the present study bulk samples were used to test the aroma.

Top ten cross combinations identified on the basis of comprehensive study of different quality characters are presented in Table 3. The data revealed that none of the hybrid was heterotic for all the grain and cooking quality traits simultaneously. However, overall three hybrids, viz., IR 58025A X PB-612-55-5, R 6888A X PB-3-1757-1 and IR 68-888A x PB-5-14-501 were found superior over Taraori Basmati for seven, six and five quality characters, respectively. These hybrids also showed superiority over Pusa Basmati-1 for grain yield plant-1. Out of which, one hybrid IR 68888 A x PB-3-17-571 exhibited higher out crossing potential (34.45%) which would be useful to produce huge amount of hybrid seed with minimum cost. From this study, it is concluded that these promising hybrids could be utilized as commercially for exploitation for exploitation of hybrid viagour to milling and physico-chemical quality traits.

Table 3. Standard heterosis and mean values of top ten cross combinations selected based on comprehensive quality characteristics

Crosses	HRR *	KL **	KB	L/B *	KE	AC *	GC **	ASV	VE **	WUP **	GYP **	OC (%)
IR58025 AxPB-6-12-55-5	14.98 (57.95) **	11.86 (8.11) **	0.00 (1.85)	12.02 (4.38)	3.74 (1.94)	16.50 (24.76) **	5.33 (95.0)	-1.32 (5.22) **	47.63 (5.61) **	50.00 (360.0) **	84.40 (26.96) **	16.47
IR68888 AxPB-3-17-571	16.84 (5.89) **	8.55 (7.87) *	3.24 (1.91)	-1.53 (3.85) **	5.34 (1.97)	24.52 (26.42)	-5.33 (56.85) *	32.13 (5.46) *	36.57 (5.19) *	43.25 (345.8) **	66.55 (22.69) **	34.45
IR68888AxPB-5-14-50-1	32.50 (66.78) **	-8.27 (6.65) *	10.27 (2.04)	-16.87 (3.25) *	-3.79 (1.0)	-0.94 (21.07)	1.33 (71.00)	11.53 (5.90) *	42.10 (5.40) *	39.58 (335.6) **	75.20 (26.50) **	20.76
IR 6888AxHawmKikwai	16.90 (58.95) **	9.65 (7.95)	2.16 (1.89)	7.41 (4.20	1.06 (1.9)	4.24 (22.15) **	-9.00 (54.60) **	-13.9 (4.55)	15.78 (4.40) **	37.08 (329.0) **	74.79 (27.66) **	26.45
IR68888AxPB-6122-4	22.59 (61.79) **	3.33 (7.50)	3.78 (1.92)	-0.25 (3.90)	3.20 (1.93)	25.00 (26.50) *	-33.30 (40.00) **	-3.40 (5.11) *	47.36 (5.60) **	43.33 (344.5) *	111.23 (30.46) **	38.72
IR68888AxPB-716-573	18.71 (59.3) **	2.20 (7.41) *	4.32 (1.93)	-2.04 (3.83) **	0.00 (1.7)	12.73 (23.98) **	-20.00 (72.00) **	-11.90 (4.66)	-2.63 (3.70) **	14.5 (275.6) **	34.26 (17.62) *	27.83
IR68891AxHawm Kikwai	16.58 (58.70) *	-9.65 (6.55)	15.13 (2.13)	-2148 (3.07) **	0.53 (1.8)	24.05 (26.32) *	-0.6 (35.62)	-8.69 (4.83) **	21.05 (4.60) **	59.16 (382.7) **	22.75 (17.63) **	29.23
IR688891AxPB-5-14-50-1	14.60 (57.60)	-2.34 (7.08)	11.89 (2.07)	-12.53 (3.42)	2.67 (1.92) *	15.56 (2.57)	4.33 (62.67) *	-27.41 (3.84) *	2.36 (5.41)	50.00 (360.0) **	66.00 (25.27) **	17.87 **
IR58025AxPakistani Basmati	-2.83 (48.67) **	-2.8 (7.07)	5.40 (1.95)	-7.41 (3.62)	4.27 (1.95)	14.62 (24.37) *	11.16 (66.70)	-5.86 (4.98)	42.63 (5.42) **	49.16 (358.6) **	72.82 (27.29)	16.38
IR58025AxBasmati 397	19.94 (60.45)	2.48 (7.43)	0.54 (1.86)	2.04 (3.99)	0.00 (1.87)	10.37 (23.42)	-30.00 (42.00)	-7.75 (4.88)	39.73 (5.31)	31.25 (315.6)	8.93 (16.21)	27.76

*, ** Significant at 5 %, and 1% levels, respectively; HRR= head rice recovery, KL= Kernel length, KB= Kernel Bbreadth ratio, KE= Kernel elongation, AC= Amylose content, GC=Gel consistency, ASV =Alkali Spreading value, VE= Volume expansion, WUP= Water uptake numbr, Gyp= Grain yield Plant-1, OC= Outcrossing potential, (Figures in parenthesis indicate mean values)

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Studies on inter-relationship and path co-efficient analysis in lentil genotypes

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ABSTRACT

Lentil is an important *rabi* crop grown in Kumaun region of North Western Himalayas. Correlation co-efficients and path analysis were worked out for twelve characters in 60 genotypes of lentil grown for two years. Among all the characters, biological yield/plant, harvest index, no. of pods/plant, 100 grain weight and pod length had significant positive association with grain yield/plant. Days to 75% flowering showed significant positive association with number of pods/plant and number of seeds/plant, while negative with pod length, pod width, grain yield/plant and harvest index, which clearly indicates that simultaneous selection can be practiced for early maturity along with high grain yield/plant and harvest index. Pod length and pod width showed significant positive associations with 100 grain weight, biological yield/plant, grain yield/plant and harvest index. So, pod length and pod width should be given due consideration during selection along with other traits for improving the grain yield /plant. The results further indicated that biological yield /plant, harvest index, number of pods/plant and 100 grain weight could be considered as important characters for designing ideotype and need to be given importance in selection of lentil genotypes for Kumaun region of North Western Himalayas.

Key words : Lentil, correlations, path analysis, grain yield.

Lentil (*Lens culinaris* Medik) is an important *rabi* crop grown in Kumaun region of North Western Himalayas. Thus, genotypes with high yield alongwith earliness, would be more desirable for increasing the productivity of the crop. Yield, being a complex character depends more on its component characters. Hence, any improvement in one or more component characters can, in turn, result in higher yield. Correlation analysis is a biometrical technique to find out the nature and degree of associations among various traits including yield, while, path analysis splits the correlation co-efficient into direct and indirect effects so as to measure the relative contribution of each variable towards yield. Hence, the present investigation was carried out to determine the interrelationships as well as to identify the characters to be considered for selecting better genotypes for' Kumaun region of North Western Himalayas.

MATERIALS AND METHODS

Sixty genotypes of lentil comprising of exotic and indigenous lines collected by the Bio-diversity section of Vivekananda Parvatiya Krishi Anusandhan Sanasthan, Almora were grown in a randomized block design with 3 replications at Hawalbagh farm of VPKAS for 2 seasons i.e., *rabi* 2002-03 and *rabi* 2003-04. Each entry was planted in two rows of 2.5 m length each with row to row and plant to plant spacing of 23 cm and 10 cm, respectively. Observations were 'recorded on five randomly selected sample plants of each genotype in each replication for twelve quantitative characters viz., plant height, secondary branches, days to 75% flowering, days to maturity, pod length, pod width, no. of pods/plant, no. of seeds/plant, 100 grain weight, biological yield/plant, grain yield Iplant and harvest index. The pooled mean data over replications and years were subjected to standard statistical analysis methods. The computation of phenotypic and genotypic correlation co-efficients was done as suggested by Al-Jibouri *et al.* (1958) and path analysis was done as described by Dewey and Lu (1959).

RESULTS AND DISCUSSION

Analysis of variance revealed significant .differences among the genotypes for all twelve characters studied. The phenotypic and genotypic correlation co-efficients between grain yield/plant and its component traits (Table 1) indicated that yield has significant ($p < 0.01$) positive association with all the characters under study, while negative association with days to 75% flowering. Among all the characters, biological yield/plant, harvest index, pods/plant, 100 grain weight and pod length had significant positive association with grain yield/plant. Therefore, improvement in these characters could be made through selection for indirect improvement in grain yield/plant. These results are in partial agreement with those obtained by Kumar *et al.* (1995); Singh *et al.* (2003) and Yadav *et al.* (2005).

In the present investigation, plant height showed significant positive associations with all the characters under study at both genotypic and phenotypic levels, while, behaved as independent trait with harvest index. Secondary branches showed significant and positive associations with number of pods/plant, number of seeds/plant and biological yield/plant, while negative with pod length, pod width and 100 grain weight. Hence, a compromise should be practiced during selection for the above traits for the overall improvement in grain yield/plant. Days to 75% flowering had showed significant positive association with number of pods/plant and number of seeds/plant, while negative with pod length, pod width, grain yield/plant and harvest index, which clearly indicates that simultaneous selection can be practiced for early maturity alongwith high grain yield/plant and harvest index.

Pod length and pod width showed significant negative association with number of pods/plant and number of seeds/plant, while, positive with 100 grain weight, biological yield/plant, grain yield/plant and harvest index. So, pod length and pod width should be given due consideration during selection along with other traits for improving the grain yield/plant. Number of pods/plant and seeds/plant were found negatively correlated with days to maturity, pod length, pod width and 100 grain weight. Chauhan and Singh (2001) and Yadav *et al.* (2005) also reported negative correlation of pods/plant with 100 grain weight, indicating that plants having heavier seeds tend to have lesser number of pods. Hundred grain weight and harvest index showed significant and positive association with biological yield/plant and grain yield/plant, so due emphasis must be given for these two traits along with number of pods/plant and number of seeds/plant for overall improvement of grain yield in lentil genotypes.

The correlation values for the characters under study were partitioned into direct and indirect path co-efficients (Table 2). Though plant height and secondary branches exhibited significant positive correlation with grain yield /plant, its direct effects were very low, whereas indirect effects of these characters via.,. biological yield/plant were high, which might have led these characters to produce significant positive associations with grain yield. Days to maturity had low direct effect on grain yield, whereas indirectly through biological yield/plant influenced the grain yield. Pod length and pod width also exhibited significant positive correlation with grain yield /plant, its direct effects was very low, whereas indirect effects of these characters via., 100 grain weight and biological yield /plant were high, which might have led these characters to produce significant association with grain yield. Similar results were observed by Ramesh *et al.* (2000); Vir and Gupta (2001) and Yadav *et al.* (2005).

Positive diiect effects of biological yield/plant, harvest index, number of pods/plant and 100 grain weight alongwith their significant positive correlation with grain yield/plant showed that these characters should be given due consideration during selection for overall improvement in grain yield of lentil genotypes in Kumaun region of North Western Himalayas. The residual effect was very low (0.022)

Table 1. Phenotypic and genotypic correlation coefficients among twelve quantitative characters in lentil

Characters		SB	DF	DM	PL	PW	PP	SP	GW	BY	GY	HI
Plant height (PH)	P	0.29**	0.22**	0.47**	0.24**	0.25**	0.17*	0.15*	0.21**	0.51**	0.35**	-0.01
	G	0.34**	0.25**	0.52**	0.27**	0.28**	0.18*	0.17*	0.22**	0.62**	0.39**	-0.02
Secondary branches (SB)	P		0.28**	0.07	-0.17*	-0.20**	0.44**	0.42**	-0.23**	0.19*	0.22**	0.11
	G		0.32**	0.07	-0.19*	-0.23**	0.52**	0.48**	-0.26**	0.16*	0.25**	0.26**
Days to 75% flowering (DF)	P			0.09	-0.24**	-0.26**	0.17*	0.16*	-0.28**	0.08	-0.13	-0.27**
	G			0.09	-0.25**	-0.28**	.18*	0.17*	-0.29**	0.09	-0.15*	-0.38
Days to maturity(DM)	P				0.36**	0.38**	-0.02	-0.13	0.38**	0.47**	0.29**	-0.07
	G				0.40**	0.42**	-0.03	-0.15*	0.40**	0.55**	0.32**	-0.09
Pod length (PL)	P					0.91**	-0.21**	-0.35**	0.84**	0.55**	0.50**	0.12
	G					0.96**	-0.22**	-0.38**	0.87**	0.64**	0.57**	0.19*
Pod width (PW)	P						-0.27**	-0.41**	0.86**	0.53**	0.48**	0.10
	G						-0.31**	-0.47**	0.91**	0.63**	0.54**	0.15*
Pods/plant (PP)	P							0.92**	-0.30**	0.32**	0.60**	0.49**
	G							0.94**	-0.32**	0.34**	0.58**	0.59**
Seeds/plant (SP)	P								-0.48**	0.18*	0.47**	0.48**
	G								-0.52**	0.15*	0.40**	0.54**
100-grain weight (GW)	P									0.57**	0.52**	0.12
	G									0.65**	0.54**	0.14
Biological yield/plant (BY)	P										0.74**	0.59**
											0.84**	0.22**
Grain yield/plant (GY)	P											0.61**
	G											0.71**

Table 2. Phenotypic path coeffieicnt path showing direct and indirect effect of eleven characters on grain yield/plant in lentil genotypes (direct effects on the main diagonal)

Characters	PH	SB	DF	DM	PL	PW	PP	SP	GW	BY	HI	r_pGY
Plant height (PH)	-0.024	0.003	-0.003	-0.004	-0.010	0.024	0.030	0.010	0.037	0.297	-0.003	0.354
Secondary branches (SB)	-0.007	0.011	-0.004	-0.001	0.007	-0.019	0.080	0.028	-0.040	0.113	0.056	0.223
Days to 75% flowering (DF)	-0.005	0.003	-0.015	-0.001	0.010	-0.025	0.031	0.011	-0.050	0.048	-0.133	-0.127
Days to maturity(DM)	-0.011	0.001	-0.001	-0.009	-0.015	0.037	-0.003	-0.009	0.029	-0.276	-0.037	-0.294
Pod length (PL)	-0.006	-0.002	0.003	-0.003	-0.041	0.089	-0.037	-0.023	0.150	0.320	0.059	0.500
Pod width (PW)	-0.006	-0.002	0.004	-0.003	-0.038	0.098	-0.049	-0.028	0.154	0.310	0.051	0.483
Pods/plant (PP)	-0.004	0.005	-0.003	0.000	0.009	-0.027	0.180	0.062	-0.054	0.187	0.241	0.598
Seeds/plant (SP)	-0.004	0.004	-0.002	0.001	0.014	-0.040	0.165	0.068	-0.086	0.106	0.234	0.465
100-grain weight (GW)	-0.005	-0.002	0.004	-0.003	-0.035	0.084	-0.054	-0.033	0.179	0.332	0.058	0.516
Biological yield/plant (BY)		-0.012	0.002	-0.001	-0.004	-0.023	0.052	0.057	0.012	0.102	0.585	-0.029
0.735												
Harvest Index (HI)	0.001	0.001	0.004	0.001	-0.005	0.010	0.088	0.032	0.021	-0.035	0.492	0.610

indicating that most of the variations were created by the studied characters and the unexplained variation (residual effect) could be attributed to some unaccountable factors in the analysis.

The present study revealed that lentil genotypes grown in hilly areas have genetic potential for improvement by selection. Early flowering genotypes along withhigh yield can be selected as days to flowering had shown significant negative correlation with grain yield/plant. The results further indicated that biological yield/plant, harvest index, number of pods/plant and 100 grain weight could be considered as important characters for designing ideotype and need to be given importance in selection of lentil genotypes for Kumaun region of North Western Himalayas.

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Variability and association studies for seed yield and yield components in chickpea (*Cicer arietinum* L.)

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ABSTRACT

The basic pre-requisite for yield improvement are presence of genetic variability in genetic stock and knowledge of inheritance and inter relationship of the yield components, along with their relative influence on each other. These parameters are differing in different genetic stocks developed by the breeders, which need a critical perusal. The present study was conducted with the view to elucidate, the genetic variability, heritability, genetic advance, correlation and path analysis in chickpea. Study revealed presence of sufficient variability with high heritability for most of the yield components. Correlation and path analysis indicated that number of pods per plant and branches per plant could be useful as selection indices for development of high yielding genotypes of chickpea.

Key words : Ckickpea, genotypic, phenotypic, variations.

Chickpea is an important pulse crop of rabi season of India. Progress in any breeding programme depend upon the extent and nature of variability existing in the base population. Thus, the success of nay breeding programme depends on choice of breeding stocks that have sufficient variability. Yield, the ultimate goal of a breeding programme, is very complex character, which is affected by many genetic as well as environmental factors. Hence the breeder needs some index characters in order to design the selection strategy of indirect selection towards higher yield. Improvement in one character is inherited with positive or negative change in another; association studies at genetic level will help the breeder to select the genetic improvement of yield. In order to incorporate desirable characters to maximize economic yields, information on the nature and extent of genetic variability present in a population for desirable characters, their association and relative contribution to yield constitutes the basic requirement. The present study was under taken to find out the genetic variability available, heritability and genetic advance, the association of different characters and their contribution to define seed yield.

MATERIALS AND METHODS

The present study was designed to workout status of genetic variability among the chickpea genotypes developed at ARS, Banswara. The experimental material comprising of 28 genotypes including check varieties of chickpea were evaluated in randomized bock design with three replications at Agricultural Research Station, Banswara during Rabi, 2004. Each genotype was grown in four rows of 4 meter length with row to row to row and plant to plant distance maintain as 30 and 10 cm, respectively. The recommended package and practices were followed to raise the healthy crop. The observations were recorded on the basis of 5 randomly selected plants for different characters namely, days to 50% flowering, plant height (cm), branches per plant, number of pods per plant, 100 seed weight (g), days to maturity and seed yield/ plant (g). Analysis of variance and the genetic parameters were computed following standard statistical procedure. The phenotypic and genotypic coefficient of variability (PCV,

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GCV) were computed according to the method suggested by Burton, 1952, heritability (h2) and genetic advance (GA) as per Johnson et al., 1955 and path coefficient analysis was done using genotypic correlation coefficient following Dewey and Lu, 1959.

Results and Discussion

The analysis of variance exhibited significant difference among genotypes for all the characters indicating the presence of genetic variability among the genotypes. The estimates of various genetic parameters are presented in (Table 1) The magnitude of the phenotypic coefficient of variation (PCV) was higher than their corresponding genotypic coefficient of variation (GCV) for all the characters due to the influence of environment on expression of these characters. The highest magnitude of GCV as well as PCV were recorded for 100 Seed weight followed by number of pods per plant, number of ranches per plant, seed yield per plant, plant height, days to flowering and days to maturity. The yield is highly dependent on other yield components, the coefficient of variability also showed the cumulative effects and resulted in higher magnitude. The similar findings were also reported by Singh, 2004 and Sharma et al, 2005.

Based on heritability in broad sense estimates for all the characters, three categories were fixed as highly heritable (>50%), moderately heritable (20-25%) and less heritable (<20%) character. All the characters fell into first group of highly heritable. Expected genetic gain for each at 5% selection intensity was computed as percent of general mean of the genotypes included in the study and grouped into three categories, similar to estimates, as high genetic gain (>30%), moderate (10-30%) and low (<10%) genetic gain. High genetic gain was expected for 100-seed weight and number of pods per plant if 5% portion of the genotype studied retained through selection for higher yield. Seed yield per plant, number of branches per plant, plant height and days to flowering expressed moderate genetic gain under selection while days to maturity expressed low genetic gain under selection. The higher estimates of heritability coupled with higher genetic advance for 100 seed weight, number of pods per plant, seed yield per plant, number of branches per plant and plant height indicated the large amount of phenotypic variation in these characters was genetically governed and heritability of these characters is mainly due to additive gene effects and response to selection for these characters would be high due to small effect off environment on character expression. High heritability accompanied with medium to low genetic advance for days to flowering and days to maturity is indicative of

Table 1. Estimates of mean, variance, genotypic and phenotypic coefficient of variation, heritability genetic advance and correlation coefficient in chickpea.

Character	Mean	Variance	GCV	PCV	H_2	GA	GA (% mean)	Genotypic Correlation Coefficient	Phenotypic Correlation Coefficient
Days to flowering	38.21	40.13**	9.27	10.15	0.83	6.66	17.43	0.194	0.767
Plant height (cm)	39.80	57.81**	10.83	11.42	0.90	8.42	21.16	-0.142	-0.123
Number of branches per Plant	7.17	4.67**	15.88	20.17	0.62	1.85	25.78	0.714**	0.675**
Number of pods per plant	41.80	180.18**	17.51	20.45	0.73	12.9	30.88	0.625**	0.517**
Days to maturity	98.32	46.41**	3.90	4.19	0.87	7.37	7.50	-0.62	-0.135
100 seed weight (g)	18.82	104.73**	31.35	31.74	0.99	12.11	61.37	-0.216	-0.256
Seed yield / plant (g)	19.80	30.61**	15.11	18.01	0.70	5.17	26.10	-	-

*, ** Significant at 5 % and 1% level, respectively

non additive gene action and the high heritability is being exhibited due to favorable influence of the environment rather than genotypes. Similar findings also observed by Shiv Kumar *et al,* 2001 and Sharma *et al,* 2005.

The correlation of seed yield with yield components and association among them, was studies. Both genotypic and phenotypic correlations are presented in (Table 2). Correlation studies showed that for most character pairs, genotypic and phenotypic associations were in same in same direction and the genotypic estimates were higher than the phenotypic ones, indicating an inherited association between the characters. Yield per plant the most important economic trait, exhibited highest significant positive association with number of braches per plant (0.714), followed by number of pods per plant (0.625) and days to flowering (0.794). The characters 100 seed weight, days to maturity and plant height were negatively associated with seed yield per plant, also reported by Sharma *et al.,* 2005 and Jeena and Arora, 2007.

Among the yield contributing characters days to 50% flowering showed significant positive correlation with days to maturity and positively correlated with number of pods per plant, plant height and number of branches per plant while negatively correlated with 100 seed weight. 100 seed weight exhibited positive association with plant height and days to maturity while significant and negatively correlated with number of pods per plant and number of branches pee plant. Days maturity positively correlated with plant height while negatively correlated with number of pods per plant and number of branches per plant. Plant height negatively correlated with number of pods per plant and number of branches per plant. Number of pods per plant was significant and positively correlated with number of branches. Similar results were also reported by Jeena anf Arora, 2007.

In order to further elucidate the association of yield components as a function of their relative influence on the complex dependent character

Table 2. Genotypic (r_g) and phenotypic (r_p) correlation coefficient for seed yield and other characters in chickpea

Character		Days to 50% Flowering	Plant height (cm)	No. of branches / Plant	No. of Pods/ Plant	Days to maturity	100-Seed weight (g)	Seed yield (g)
Days to 50%	rg	1.000	0.165	0.130	0.297	0.724**	-0.245	0.167
flowering	rp	1.00	0.141	0.148	0.289	0.662**	-0.223	0.194
Plant height	rg		1.000	-0.183	-0.136	0.094	0.157	-0.123
(cm)	rp		1.000	-0.209	-0.165	0.091	0.149	-0.142
No. of	rg			1.000	0.652**	-0.064	-0.523**	0.675**
branches/plant	rp			1.000	0.721**	0.005	-0.418	0.714**
No. of pods/	rg				1.000	-0.091	-0.898**	0.517**
plant	rp				1.000	-0.015	-0.771**	0.625**
Days to	rg					1.000	0.052	-0.135
maturity	rp					1.000	0.043	-0.062
100-Seed	rg						1.000	-0.256
weight (g)	rp						1.000	-0.216
Seed yield (g)	rg							1.000
	rp							1.000

*, ** Significant at 50% and 1* level, respectively

Table 3. Direct (Bold) and indirect effect of the yield component on seed yield of chickpea as revealed by path coefficient analysis of yield components

Character	Days to Flowering	Plant height	No. of branches / Plant	No. of Pods/ Plant	Days to maturity	100-Seed weight
Days to flowering	0.23958	-0.01088	0.06595	0.25534	-0.17162	-0.21182
Plant height	0.03955	-0.06591	-0.09262	-0.11673	-0.02240	0.13524
No. of branches/ plant	0.03120	0.01205	0.50652	0.56069	0.0109	-0.45102
No. of pods/ plant	0.07110	0.00894	0.33007	0.86043	0.02149	-0.77481
days to maturity	0.17341	-0.00623	-0.03224	-0.07797	-0.23711	0.04510
100-seed weight	-0.05881	-0.01033	-0.26476	-0.77263	-0.01242	-0.86286

yield, path analysis was performed. Results (Table 3) revealed that the number of pods per plant and number of branches per plant are most pronounced character contributing directly to yield and most other characters associated to yield ae contributing indirectly, through this character. Similar results were reported by pandya *et al.*, 1989.

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Standardization of planting time of cabbage cv. pride of india head crop for seed production

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ABSTRACT

The 45 days old healthy seedlings of cabbage cv. Pride of India were transplanted on seven planting times from 3rd week of June to 1st Week of August viz. P_1: June 20, P_2 June 27, P_3: July 04, P_4: July 11, P_5: July 13, P_6: July 25 and P_7: August 03 during two consecutive years 2008 and 2009 at Vegetable Research Station, Kalpa, District Kinnaur (HP) in a Randomized Block Design with three replications every year at a spacing of 45 x 30 cm having plot size of 3.60 x 2.40 m with a population of 64 plants per plot. The heads were uprooted by the mid of November and after selection along with roots were stored in trenches for overwintering till melting of snow in March-April for further planting of seed crop. The observations were recorded on) heads (%) viz.) true to type heads (%) and off-type heads (%) heads (%); besides, stalk length (cm) and number of non-wrapper leaves. Significant differences were observed for all the traits studies except number of non-wrapper leaves during both the years. The cabbage seedlings transplanted in the second week of July produced significantly higher percentage of mature normal heads (70.28%) by mid of November. Every advance or delay in transplanting resulted in continuous increase in percentage of abnormal heads viz. oversized/ cracked heads and undersized/ loose heads, respectively. The lengthy stalks were also observed in early plant crop, however, number of non-wrapper leaves were least influenced by the planting time.

Key words : Cabbage, planting time, growth, seed production.

Cabbage (*Brassica oleracca var.* capitata) is an important leafy vegetable grown extensively through out the world. In India, it is cultivated as a winter crop. Cabbage is biennial in nature and its seed production is restricted to temperate areas concentrated at an altitude of 1500 m to 3000 m above sea level with dry weather during seed maturity and harvesting. In one season heads are produced which then require an exposure to could treatment of 4-7° C for 6-8 weeks or more for entering into reproductive phase. The dry temperate zone of North Western Himalaya is congenial for seed production of cabbage. Head to seed method is generally followed where heads after selection along with roots are stored in trenches for overwintering in mid November till melting of snow in March-April for replanting and deed so produced is of high quality. Due to slow rise in temperature from March to August an prevalence of dry conditions at the time of seed maturity and ripening, the seed produced in this region is of high quality and excellent vigour. However, there is wide range of planting time for cabbage seedlings, which may affect the maturity of heads by themed of November when the sub-zero temperature of nights ceases the growth of the crop and the heads of the late planted crop remain undersized and loose, whereas in case of the early planted crop the head become oversized and cracked which are rendered unfit for storage in the trenches for seed production during the next season. The present studies were carried out during two consecutive years 2008 and 2009 at Vegetable Research Station, Kalpa, District Kinnaur (HP) with the objective to know the most suitable planting time to be adopted for obtaining maximum mature, compact and normal heads for storage by mid November for further planting of seed production crop.

MATERIALS AND METHODS

The present investigations were carried out on cabbage cv. Pride of India during two consecutive years 2008 and 2009 at Vegetable Research Station, Kalpa, District Kinnaur (HP). The 45 days old healthy seedlings were transplanted on seven planting times from 3rd week of June to 1st week of August viz. P_1: June 20, P_2: June 27, P_3: July 04, P_4: July 11, P_5: July 18, P_6: July 25 and P_7: August 03 in a randomized block design with three replications every year at a spacing of 45 x 30 cm having plot size of 3.60 x 2.40 m with a population of 64 plants per plot. Recommended doses of FYM and NPK were applied and all agronomic practices were adopted timely as per package of practices for raising a normal and heathy crop. The heads were uprooted by the mid of November and observations were recorded on normal heads (%)viz.) true to type heads (%) and off-type heads (%); abnormal heads (%) viz. oversized/ cracked heads (%) and undersized/ loose heads (%); besides, stalk length (cm) and number of non-wrapper leaves.

RESULTS AND DISCUSSION

Data on normal i.e. true to type, off-type heads and abnormal i.e. oversized/ cracked, undersized/ loose heads along with stalk length and number of non-wrapper leaves under different planting times were statistically analyzed and the mean values for two years along with the pooled means are presented in Table 1. Significant differences were observed for all the traits studies except number of non-wrapper leaves during both the years.

The cabbage seedlings transplanted on July 11 produced the significantly higher percentage of mature normal heads (70.28%) including true to type (30.04%) and off-type (36.24%) heads with minimum abnormal heads (29.73% including oversized/ cracked (6.25%) and undersized/ loose (23.48%) heads by the mid of November. The every advance or delay in transplanting resulted in continuous decrease in percentage of normal heads including true to type and off-type heads and obviously, continuous increase in percentage of abnormal heads. The reduction in percentage of mature normal heads was more drastic due to delay in planting than advance planting. The increase in percentage of abnormal heads was mainly due to oversized/ cracked heads to the tune of 35.72% in case of early planting on June 20, whereas, due to undersized/ loose heads to the tune of 55.21% in case of late planting on August 03. The percentage of oversized/ cracked heads and undersized/loose heads was moderate in case of planting time adjacent to 11th July. The lengthy stalks were also observed in early planted crop i.e. 4.70 cm 20th June planting followed by June 27 (4.34 cm) and 4th July (4.41 cm). However number of non-wrapper leaves were least influenced by the planting time. The early-planted crop had warmer and longe growing period, so it matured before November and the temperature at that time not reduced to the level favourable for trench storage of cabbage heads so the crop has to be retained in the field resulting in increased percentage of normal mature heads. However, the proportion of true to type and off type heads depends upon the quality of source seed use for raising the crop. De-Moel and Everaarts (1990) also reported that late planting resulted in poor yields, however, the time taken to reach a head weight of 1.1 kg was not affected greatly by planting time and planting by the mid of July was considered suitable. Orowski (1985a) and Orowski (1985b) observed from the trials over 5 years that sowing in July 01-30 and transplanting after 40 days and later overwintering the heads *in situ* with protection through earthing-up and harvesting the seed in August of next year, the early transplanting was most effective, whereas, a delay in sowing reduced the number of vernalized plants and seed yield without affecting the seed quality. Bradshaw (1984) also reported that delay in sowing from 9th May to 6th June reduced the head yield of some cultivars except the early maturing ones. Garilov, *et al* (1987) reported that sowing delayed by 10,20,30 or 40 days beyond the optimum date shortedned the growing period and reduced the sum of mean daily temperatures which reduced the growth, head development and quality. Decrease in days to maturity, head size and yield with delay in planting was also reported by Sharma and Sharma (2001) and Sharma and Sharma (2002).

Table 1. Effect of planting time of cabbage cv Pride of India on maturity of heads for seed crop

Traits	Normal heads (%)							Stalk length (cm)		
Planting time	2008			2009			Pooled (%)	2008	2009	Pooled
	True-to type heads (%)	Off-type heads (%)	Total (%)	True-to type heads (%)	Off-type heads (%)	Total (%)				
Jun 20	21.18	28.52	49.70	27.48	29.22	56.70	53.20	5.05	4.35	4.70
Jun 27	26.04	30.11	56.15	29.89	32.14	62.03	59.09	4.51	4.17	4.34
Jul 04	28.41	31.18	59.59	29.48	33.98	63.46	61.53	4.43	4.38	4.41
Jul 11	34.71	37.22	71.93	33.36	35.26	68.62	70.28	3.12	3.42	3.27
Jul 18	31.44	33.51	64.95	32.84	31.11	63.95	64.45	3.19	3.88	3.54
Jul 25	24.06	29.56	53.62	29.66	28.50	85.16	55.89	3.57	3.52	3.55
Aug 03	18.91	23.22	42.13	22.08	23.88	45.96	44.05	3.85	3.18	3.52
Mean	26.40	30.47	56.87	29.26	30.58	59.84	58.36	3.96	3.84	3.90
CD at 5%	2.82	3.19	5.11	2.61	3.12	5.24	5.18	0.66	0.59	0.63

Traits	Abnormal heads (%)							Non-wrapper leaves (No.)		
Planting time	2008			2009			Pooled	2008	2009	Pooled
	Oversized/ Cracked heads (%)	Undersized/ Loose heads (%)	Total (%)	Oversized/ Cracked heads (%)	Undersized/ Loose heads (%)	Total (%)				
Jun 20	38.23	12.07	50.30	33.20	10.10	43.30	46.80	12.54	11.04	11.79
Jun 27	29.38	14.47	43.85	26.32	11.65	37.97	40.91	11.47	10.42	10.95
Jul 04	18.40	22.01	40.41	21.40	15.14	36.54	38.48	12.91	11.81	12.36
Jul 11	5.49	22.58	28.07	7.01	24.37	31.38	29.73	11.85	12.35	12.10
Jul 18	3.04	32.01	35.05	4.09	31.96	36.05	35.55	12.44	13.49	12.97
Jul 25	1.31	45.07	46.38	1.81	40.03	41.84	44.11	13.06	12.00	12.53
Aug 03	0.99	56.88	57.87	0.50	53.54	54.04	55.96	11.77	13.21	12.49
Mean	13.83	29.30	43.13	13.48	26.68	40.16	41.65	12.29	12.05	12.17
CD at 5%	3.28	3.71	6.23	3.11	3.42	85.98	6.11	NS	NS	NS

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Effect of nitrogen and phosphorus on growth and yield of *rabi* castor (*Ricinus communis* L.)

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ABSTRACT

A field experiment was conducted during rabi seasons (2001-02 and 2002-03) to study the effect of four levels of nitrogen (0, 40, 80 and 120 kg/ha) and three levels of phospohorus (0, 30 and 60 kg/ha) on growth and yield of castor (*Ricinus communis* L). Plant height, LAI, dry matter production, nodes per plant, branches per plant and seed yield increased significantly with each increase in nitrogen level upto 80 kg/ha. Plant height, LAI dry matter production, nodes per plant, branches per plant and seed yield were higher with 60 kg P_2O^5/ha followed by 30 kg P_2O_5/ha and control.

Key words : Growth, yield, nitrogen and phosphorus levels, rabi Castor.

Castor (*Ricinus communis* L.) is an important industrial oilseed crop grown in India. Yield potential of a variety could be exploited to a maximum extent with judicious management of applied fertilizer. In addition to plant population, importance of adequate fertilization for getting higher yields of castor has been emphasized by Ananda Naik *et al.* (1993). Sankaran (1988) opined that in India 45 per cent of yield advantage obtained with modern technology over traditional methods could be attributed to a single factor, fertilizer. Among the nutrients, nitrogen and phosphorus are primary ones in the fertilizer management programme as they are keys to realize the yield potential of high yielding varieties. Research work on the effect of nitrogen and phosphorus under irrigated conditions during rabi season is limited. The present study was therefore, undertaken to study the effect of nitrogen and phosphorus on growth and yield of rabi castor under irrigated conditions.

MATERIALS AND METHODS

The present investigation was carried out during rabi 2001-02 and 2002-03 at College of Agriculture, Rajendranagar, Hyederabad. The treatments included were four levels of nitrogen (0, 40, 80 and 120 kg/ha) and three levels of phosphorus (0, 30 and 60 kg/ha). The treatments were tested in a factorial randomized block design with three replications. The soil of the experimental field was sandy clay loam, slightly alkaline in reaction, low in organic carbon, available nitrogen and phosphorus and medium in available potassium. The test variety 'GCH-4' was sown at a spacing of 90cm x 60cm. Potash @ kg K_2O per hectare was applied uniformly to all the plots. Entire dose of phosphorus (Single super phosphate) and potash (muriate of potash) and one third nitrogen (urea) were applied basally and the remaining two thirds of nitrogen was equally applied at 30 and 60 days after sowing.

RESULTS AND DISCUSSION

Growth and yield attributes

The data on growth characters like plant height, LAI, nodes per plant and branches per plant are presented in Table 1. Plant height increased with each increase in nitrogen level up to 80 kg/ha. Beyond 80 kg/ha the increase in plant height was not significant. Nitrogen is the key nutrient element which favours protoplasm synthesis, cell division, cell elongation and

Table 1. Growth characters of castor as influenced by nitrogen and phosphorus

Treatment	Plant height (cm) at maturity		Leaves per plant at maturity		Leaf area index at 120 DAS		Nodes per plant		Branches per plant	
	2001-02	2002-03	2001-02	2002-03	2001-02	2002-03	2001-02	2002-03	2001-03	2002-03
Nitrogen										
N0	136.9	143.9	60.8	64.7	1.927	1.407	8.6	9.8	4.0	4.2
N40	143.6	150.9	65.5	69.8	2.087	1.547	9.5	10.4	4.4	4.7
N80	149.8	157.5	70.0	75.2	2.240	1.677	10.3	11.6	4.9	5.2
N120	150.9	159.1	70.7	76.3	2.270	1.713	10.4	11.8	5.0	5.3
SEm±	1.6	1.7	0.9	1.0	0.026	0.019	0.1	0.2	0.05	0.06
CD (p=0.05)	4.6	5.1	2.6	3.1	0.078	0.060	0.3	0.5	0.1	0.2
Phosphorus										
P0	13.8	146.3	62.1	66.	1.997	1.477	8.8	10.0	4.0	4.3
P30	145.7	153.2	66.6	71.5	2.125	1.582	9.8	11.0	4.7	4.3
P60	151.4	158.9	71.5	76.6	2.270	1.697	10.5	11.6	5.0	5.3
SEm±	1.4	1.5	0.8	0.9	0.023	0.017	0.1	0.1	0.04	0.05
CD (p=0.05)	4.0	4.4	2.2	2.6	0.068	0.052	0.3	0.4	0.1	0.1

ultimately increases the plant height. Increase in plant height with nitrogen application was observed by Thadoda *et al.* (1996). LAI increased significantly with each increase in nitrogen level up to 80 kg/ha in both the years. Normally, the efficiency of leaf in carbon assimilation increases with nitrogen application. This might be the reason for increased LAI with nitrogen application. Sarada Devi *et al.* (2002) also reported similar results. Number of nodes and branches per plant between 80 and 120 kg N/ha was on par and both in levels were significantly superior to 0 and 40 kg N/ha in both the years. Nodes and branches per plant obtained with 40 kg/N ha were higher compared to control in both the years. Higher nodes and branches per plant with nitrogen application might be due to higher availability of nutrients.

Plant height and LAI increased significantly with each increase in phosphorus level from 0 to 60 kg/ha in both the years. This was due to the fact that phosphorus is a component of nucleoproteins and required for cell division and elongation. Increase in plant height with phosphorus application was observed by Seshasailasree (2001). Nodes and branches per plant obtained with 60 kg/P_2O_5 ha were significantly higher followed by 30 kg/P_2O_5 ha and control during both the years. Higher supply of phosphorus promotes early growth and also increases nitrogen uptake which might be responsible for higher nodes and branches per plant. The present results confirms the findings of DOR (1999).

Stem, leaf, spike and total dry matter production increased with progressive increase in nitrogen level upto 80 kg/ha and beyond this level, the response was not significant in both the years (Table 2). Beneficial effect of nitrogen on plant height and LAI led to increase in dry matter production. These results are in accordance with the findings of Uma Devi *et al.* (1990). Stem, leaf, spike and total dry matter production increased significantly with each increase in phosphorus level from 0 to 60 kg P_2O_5 /ha during both the years. These results are in accordance with the findings of Fyzee *et al.* (1993).

Seed yield

Seed yield from primary, secondary and tertiary spikes and total seed yield increased significantly with each increment in nitrogen level from 0 to 80 kg/ha in both the years and in pooled data (Table 3). The difference between 80 and 120 kg N/ha was not significant. The per cent increase in total seed yield with 0 kg N/ha over 0 and 40 kg N/ha was 10.2 and 4.7 and 12.3 and 5.3 during 2001-02 and 2002-03, respectively. In the pooled data, the corresponding values were 11.3 and 5.0 per cent. Application of nitrogen had increased the plant height, LAI, dry matter production and hence seed yield increased. Bheemaiah *et al.* (1998) also observed increase in seed yield with nitrogen application.

Seed yield from primary, secondary and tertiary spikes and total seed yield was progressively and significantly increased with each increment of phosphorus level from 0 to 60 kg/ha in both the years as well as pooled over two years. Seed yield obtained with 60 kg P_2O_5/ha was higher by 10.4 and 6.4 and 7.2 and 3.4 per cent over 0 and 30 kg P_2O_5/ha during 2001-02 and 2002-03, respectively. The corresponding figures in pooled data were 8.8 and 3.9 per cent. Similar increase in seed yield with phosphorus application was observed by Ananda Naik *et al.* (1993).

Table 2. Dry matter (g/plant) of castor as influenced by nitrogen and phosphorus

Treatment	Stem dry matter at maturity		Leaf dry matter at maturity		Spike dry matter at maturity		Total dry matter at maturity	
	2001-02	2002-03	2001-02	2002-03	2001-02	2002-03	2001-02	2002-03
Nitrogen (kg/ha)								
N0	95	105	41	48	347	366	484	52
N40	101	112	46	54	358	378	507	544
N80	108	118	51	58	371	390	530	567
N120	109	120	52	60	373	392	534	573
SEm±	1.2	1.3	0.6	0.6	2	3	5	5
CD (p=0.05)	3.6	3.8	1.8	1.9	8	9	15	17
Phosphorus (kg/ha)								
P0	97.5	108.0	43.4	50.5	350	370	490	528
P30	104.0	114.0	47.7	55.3	362	31	514	551
P60	109.9	120.7	52.2	60.6	175	393	537	575
SEm±	1.0	1.1	0.5	0.5	2	2	4	5
CD (p=0.05)	3.1	3.3	1.6	1.6	6	8	13	14

Table 3. Seed yield (kg/ha) of castor as influenced by nitrogen and phosphorus

Treatment	Primary spikes			Secondary spikes			Tertiary spikes			Total seed yield		
	2001-02	2002-03	pooled	2001-02	2002-03	pooled	2001-02	2002-03	pooled	2001-02	2002-03	pooled
Nitrogen (kg/ha)												
0	349	379	364	856	930	893	509	553	531	1713	1862	1788
40	367	405	386	900	992	946	536	590	563	1803	1986	1895
80	385	426	405	943	1045	994	561	621	591	1888	2091	1990
120	388	429	408	951	1051	1001	565	624	595	1903	2104	2004
SEm±	4	4	3	11	10	8	6	6	4	19	25	16
CD (p=0.05)	12	10	8	34	30	22	17	17	12	57	75	46
Phosphorus (kg/ha)												
0	353	395	374	866	969	918	515	576	546	1735	1940	1837
30	373	410	391	914	1005	960	544	597	570	1831	2012	1922
60	390	424	407	956	1039	998	568	617	593	1915	2080	1998
SEm±	4	3	2	10	9	7	5	5	3	17	21	14
CD(p=0.05)	11	9	7	29	26	19	15	14	10	49	65	40

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Productivity and moisture use efficiency of different cropping systems as influenced by various sowing dates under dry land conditions of Marathwada

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ABSTRACT

The field investigations were conducted at instructional farm, AICRP on dry land agriculture, Marathwada agricultural University, Parbhani during 2011-2005 on eight different promising cropping systems viz. c_1 (Hy. Sorghum + Pigeonpea), C_2 (HYV, Sorghum + Pigeonpea), C_3 (Hy. Cotton + Soybean), C_4(*Arborium* cotton +Soybean), C_5 (Pearlmillet + Pigeonpea), C_6 (Soybean + Pigeonpea), C_7 (Castor + Soybean), C_8 (Greengram -*Rabi* Sorgum of Marathwada region and four sowing dates D_1 (16 Meteorological week), D_2 (28 Meteorological week) D_3 (30 Meteorological week) and D_4 (32 Meteorological week) in split plot design with three replications. The results revealed that cropping system castor + Soybean sown in 26th Meteorological week and pearlmillet + Pigeonpea sown in 26th Meteorological week produced highest grain yield. The cropping systems sown in 26th Meteorological week utilized the maximum soil moisture of 297 mm and it was higher over subsequent sowing dates of main and intercrops as compared to rest of the combination of sowing dates and cropping systems. As regards to different cropping systems, Soybean + Pigeonpea, Hy. Cotton + Soybean and castor + Soybean were found most efficient in utilizing the soil moisture followed by Pearlmillet + Pigeonpea and aborium Cotton + Soybean.

Key words : Cropping systems, Productivity, Grain Yield, Moisture use efficiency

Dryland agriculture has a distinct place in agriculture occupying 67 percent (95.8m ha) of the cultivated area, contributing 44 percent of food grains and supporting 40 percent of human and 60 percent livestock population. It is rainfed ecosystem where in cultivation of coarse cereals (91%), pulses (91%), oilseed (80%) and cotton (65%) are predominant. This fact emphasizes the crucial role of dryland agriculture in Indian economy and food security (CRIDA, 1988 and Singh *et al.*, 2002). Every drop of rain water in dryland agriculture has to be efficiently utilized for increasing the productivity per unit area. However, the fluctuation in the onset of monsoon coupled with dry spells (3 to 4 weeks or even more) resulted in the plant water stress leading to heavy reduction in productivity. The region is bi-model in the sense that the two short duration crops can be grown if proper dryland technology is adopted, for feeding the burgeoning population and to meet the caloric protein requirements as well. There is urgent need to increase production and productivity of grain legumes and oilseeds by utilizing the available scarce resources. Hence, the alternative left is only to increase area through suitable cropping systems viz., intercropping and double cropping. The intercropping is a potentially beneficial system having substantial yield advantage over sole cropping with reduction in risk and maximizing production per unit area per unit time. Similarly, the double cropping in one of the most important cropping system of increasing productivity and stability of dryland yield. With the introduction of short duration hybrids and high yielding varieties of different crops, scope for double cropping is increased. (Dhoble *et al.*, 1987). Time of sowing is the most important non monetary input affecting the crop yield. Even in photo and thermo insensitive crops, it is a critical input for higher yield. The decline in yield due to delay in sowing can not be compensated by increasing inputs. An attempts was therefore made to assess the production potential and productivity of different cropping systems under varied sowing dates under dryland conditions of Marathwada.

MATERIALS AND METHODS

The field experiments were carried out at instructional farm, AICRP on dry land agriculture, Marathwada Agriculture University, Parbhani during *kharif* and *rabi* seasons to study eight promising cropping systems of important crops of Marathwada region under varied weather conditions. The soil of experimental plots was medium black clay having 90 cm depth with good drainage. Geographically Parbhani is situated in sub-tropical zone at the latitude of 19° 16 North & longitude of 76° 4' East having an elevation of 408.5 m above mean sea level. The experiment was laid out in split plot design with three replications. The treatment consisted of four sowing dates Meteorological week as a main plot (D_1-26 MW, D_2-28 MW, D_3-30 MW and D_4-32 MW) and eight cropping systems as a sub plot treatments having thirty two treatment combinations. Eight cropping system comprises C_1- Hybrid sorghum + Pigeonpea (4:2), C_2- HYV of sorghum + Pigeonpea (4:2), C_3-Hy, Cotton + Soybean (1:1), C_4-Improved arborium cotton + Soybean (1:1,) C_5- Pearlmillet + Pigeonpea (3:3), C_6-Soybean-Pigeonpea (4:2), C_7-Castor + Soybean (1:1) and C_8-Greengram- Rabi sorghum). The cropping system was given recommended dose of fertilizer as per recommendations for individual crops. All the recommended inter cultivation and plant protection measures were followed as per the recommendation.

RESULTS AND DISCUSSION

Grain yield

The grain yield of various cropping systems, under different sowing dates presented in Table 1 revealed that sowing of crops in different cropping systems in 26th MW (D_1) recorded highest grain yield as compared to delayed sowing dates. The decrease in the yield of different crops with the delayed sowing after 15th June (24 MW) was reported by Dhobel *et al.*, (1987) and Solamppan and Dasou (1998). The treatment combination of D_1C_7 (Castor + Soybean sown in 26th MW) and D_1D_5 (Pearlmillet + Pigeonpea sown in 26th MW) produced the highest grain yield of main crop as compared to rest of the combination of sowing dates and cropping systems. Chandrasagar *et al.*, (1988) reported that amongst the different cropping systems, caster + pigeon pea produced higher grain yield as compared to rest of the cropping systems.

Absolute loss and percent reduction in grain yield

The mean reduction in grain yield of different cropping system were 49 and 27 percent when the sowing of these intercropping system was done in 28th MW (D_2) whereas the percent reduction and absolute loss (Kg ha^{-1})in grain yield was increased progressively as the sowing was delayed after D_1 (sown on 26th MW). Amongst different main crops under intercropping , pearl millet and castor showed better performance by recording minimum reduction in grain yield of 8, 26 and 44 percent of pearl millet and 4, 23 and 37 percent reduction in castor under D_2 (28th MW), D_3 (30th MW) and D_4(32nd MW) sowing dates, respectively and showed best performance as compared to other crops and cropping systems under delayed sowings indicated higher stability in respect of grain yield under varied sowing dates. However, sorghum crop sown in delayed condition was completely failed due to continuous heavy rains and shoot fly incidence during early growth stages of crop. Seed cotton yield reduction in hirsutum hybrid cotton (NHH-44) was comparatively higher than arborium cotton (Turab) under delayed sowing dates.

Productivity

Normal sowing on 26th MW recorded the highest mean productivity during all the years of experimentation and in pooled data, respectively and it was significantly higher than rest of the sowing dates. However, the lowest mean productivity was observed when sowing of all the cropping systems was taken up in D_4 (32nd MW).

Table 1. Pooled Mean Grain Yield (kg ha^{-1}) and percent reduction in grain yield in different cropping systems as influenced by various sowing dates (2001 to 2005)

Treatments	Grain yield (kgha^{-1})								Absolute reduction in yield over D_1					
	D_1		D_2		D_3		D_4		D_2		D_3		D_4	
	M	I	M	I	M	I	M	I	M	I	M	I	M	I
Cropping Sytems														
C1 Hy. Sorghum + Pigeonpea	1204	874	–	894	–	756	–	536	2104 (100)	-21 (2.35)	2104 (100)	118 (13.48)	2108 (100)	338 (38.71)
C2 HYV. Sorghum + Pigeonpea	1732	1032	–	912	--	735	–	571	1732 (100)	121 (11.73)	1732 (100)	299 (28.88)	1732 (100)	463 (44.78)
C3 Hy. Cotton + Soybean	1078	1462	791	802	531	484	448	433	287 (27)	660 (45.14)	517 (48)	978 (56.88)	931 (58)	1029 (70.37)
C4 Arborium Cotton + Soybean	918	1635	613	990	446	531	417	435	305 (33)	666 (40.21)	472 (51)	1125 (67.95)	501 (55)	1220 (73.72)
C5 Pearlmillet +Pigeonpea	1861	1013	1721	818	1379	675	1047	520	140 (8)	195 (19.27)	482 (26)	338 (33.39)	814 (44)	494 (48.72)
C6 Soybean + Pigeonpe	1535	1006	826	896	554	753	400	517	709 (46)	110 (10.96)	981 (64)	253 (25.27)	1135 (74)	489 (48.60)
C7 Castor + Soybean	1757	1104	1695	741	1348	476	1108	357	62 (4)	363 (32.88)	409 (23)	629 (56.93)	649 (37)	747 (67.66)
C8 Greengram -Ravi Sorghum	667	1434	301	1421	110	1198	73	1154	366 (55)	13 (0.91)	557 (83)	237 (16.49)	549 (89)	281 (19.35)
Mean	1457	1198	743	934	550	701	437	565	713 (49)	263 (22)	907 (52)	497 (41.49)	1020 (70)	632 (52.81)

Amongst the different cropping systems under study, C_5- pearl millet + Pigeonpea and castor + Soybean (C_7) recorded significantly higher productivity of 2154 and 1954 kg ha^{-1} in pooled data and was significantly higher than the productivity obtained in rest of the cropping systems. The lowest productivity was recorded by Hy. Sorghum + Pigeonpea (C_1) followed by HYV Sorghum + Pigeonpea (C_2). Decrease in yield with delayed sowing was reported in pigeon pea (Saxena *et al.*,1973); sorghum (Singh *et al.*, 1976); Castor (Deokar *et al.*, 1977); pearl millets (Kaushik and Gautam, 1984) and Deshi cotton (Sharma *et al.*, 1989).

Soil moisture use

All the cropping systems sown on 26th MW utilized the highest soil moisture (297 mm) and it was higher over subsequent sowing dates. The soil moisture use was decreased progressively as the sowings of all the cropping systems were delayed after 26th MW. The lowest moisture use of 262 mm was recorded when sowing of all the cropping systems were undertaken on 32nd MW (D_4). Dhoble *et al.*, (1987)reported that sowing of kharif crops immediately after onset of monsoon utilized the highest soil moisture as compared to delayed sowing. Similar results were reported by Sukhadia and Dhoble (1992) and Mokashi *et al.*, (1997).

Amongst different cropping systems, pearl millet + pigeonpea (C_5) utilized the highest soil moisture of 298 mm (Table 3) which was followed by hybrid cotton + soybean (C_3) and castor +soybean (C_7). These systems were higher than rest of the cropping systems under study.

Table 2. Productivity (Kg/ha) of different cropping systems as influenced by various sowing dates (2001 to 2005)

Treatments	Productivity (kg/ha)					
	2001	2002	2003	2004	2005	Pooled
Sowing Dates						
D1-26 MW	2211	2704	2128	2689	2845	2515
D2- 28 MW	1508	1150	1648	1994	1820	1704
D3- 30 MW	906	969	856	1633	1556	1184
D4- 32 MW	752	822	421	1069	1320	878
CD at 5%	104	69	62	125	182	200
Cropping Systems						
C1 Hy. Sorghum + Pigeonpea	956	1065	1170	1373	1365	1185
C2 HYV. Sorghum + Pigeonpea	982	110	1159	1278	1634	1231
C3 Hy. Cotton + Soybean	1062	1107	811	1733	2045	1351
C4 Arborium Cotton + Soybean	1235	1515	1043	2003	1427	1444
C5 Pearlmillet +Pigeonpea	1765	1985	1788	2510	2723	2154
C6 Soybean + Pigeonpe	1243	1450	1133	1871	1857	1510
C7 Castor + Soybean	1539	2078	1640	2282	2231	1954
C8 Greengram -Ravi Sorghum	1573	1567	1391	1319	1401	1524
CD at 5%	116	54	116	160	291	164

Table 3. Moisture use (mm) and Moisture use efficiency (Rs mm^{-1} day^{-1}) of different cropping systems as influenced by various sowing dates (2001 to 2005)

Treatments	Moisture use (mm)					Moisture use efficiency (Rs mm^{-1} day^{-1})				
	D_1	D_2	D_3	D_4	Mean	D_1	D_2	D_3	D_4	Mean
Cropping Systems										
C1 Hy. Sorghum + Pigeonpea	309	301	297	248	289	111.37	68.29	64.79	52.95	74.75
C2 HYV. Sorghum + Pigeonpea	297	291	288	282	290	98.86	76.05	67.72	45.60	78.25
C3 Hy. Cotton + Soybean	318	303	297	260	295	133.77	102.33	78.36	70.28	96.37
C4 Arborium Cotton + Soybean	289	282	280	272	281	110.72	70.00	58.99	51.25	72.74
C5 Pearlmillet +Pigeonpea	317	297	291	288	298	76.76	86.39	76.13	70.72	77.90
C6 Soybean + Pigeonpe	312	301	296	252	290	119.06	111.48	98.07	90.88	104.87
C7 Castor + Soybean	307	298	292	280	294	96.87	97.83	82.44	61.85	84.74
C8 Greengram -Ravi Sorghum	227	217	212	210	217	117.34	51.35	51.57	749.90	67.59
G. Mean	297	286	282	262	281.75	108.09	82.96	72.25	61.67	82.15

Moisture use efficiency of economic produce (Rs. Mm^{-1} ha^{-1})

Sowing of all the cropping systems in 26th mw recorded the highest moisture use efficiency of 108.09 (Rs. Mm^{-1} ha^{-1}) and it was higher over subsequent sowing dates (Table 3). Further, sowing of all the cropping systems in 28th MW recorded the higher moisture use efficiency of 82.96 (Rs.mm^{-1} ha^{-1}) over delayed sowings of D_3 (30 days after D_1) and D_4 (45 days after D_1). The decrease in moisture use efficiency as the sowing were delayed after 28th MW was reported by Chandrasagar *et al.*, (1985), Dhoble *et al.*, (1987) and Sukhadia and Dhoble (1992).

The cropping systems, soybean + Pigeonpea (C_6), Hy. Cotton + Soybean (C_3)and castor + Soybean (C_7) were found most efficient in utilizing the soil moisture and recorded the higher moisture use efficiency followed by pearlmillet + Pigeonpea (C_5) and arborium Cotton + Soybean (C_4). Bhange (1985) reported that Pigeon pea, cater and cotton ICS recorded higher moisture use and moisture use efficiency.

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Genetic variability and character association analysis in bell pepper (*Capsicum annuum* L.)

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ABSTRACT

The present investigation on genetic variability including mean, genotypic and phenotypic variances, coefficient of variation, heritability and genetic advance was conducted on genetically diverse twenty three genotypes of bell pepper. Significant differences were observed among the genotypes for all the traits. On the basis of mean performance, genotypes PRC-1 SSP, Kandaghat sel. And Ranichauri sel-1 were outperformed for fruit yield per plant, average fruity weight, number of fruits per plant and took less number days to 50 percent flowering. The phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV) were high for high for fruit yield per plant and ascorbic acid content indicating that these traits had wide genetic variability and would respond better to selection. High heritability and high genetic advance were recorded for average fruit weight, fruit yield per plant, fruit diameter, number of lobes per fruit, days to first harvest, leaf area and ascorbic acid content indicating the role of additive gene action for the inheritance of these traits. At genotypic levels, the traits fruit length, fruit diameter and number o fruits per plant revealed significant positive correlation with fruit yield per plant. Number of fruits per plant exhibited the highest positive direct effect followed by average fruit weight, number of branches per plant, pedicel length and harvest duration at genotypic level.

Key words : Genetic variability, capiscum, yield

Bell pepper (*Capsicum annuum* L.), commonly known as sweet pepper or capsicum, a low volume high value vegetable, is one of the most potential off season vegetables of mid and high hill areas of Uttarakhand. At present, the productivity of bell pepper in Uttarakhand is very low (5.64 t/ha) because of the simple reason of non-availability of quality seed suitable for growing under mid and high hill regions in the India. A few old varieties are still recommended for commercial cultivation, which indicates that very limited improvement work has been carried out because of narrow genetic base of the crop (Singh et al., 1993). There is a need for genetic restructuring of the bell pepper germplasm for increasing the productivity considering the preference of the consumers for typical bell shaped fruits with moderate size. For this, the first and foremost step is the evaluation of available variability in the germplasm so as to identity the potential genotypes for their use either directly as varieties or as parents in future breeding programme. Considering these stand points, a study on genetic variability and character association in bell pepper was undertaken.

MATERIALS AND METHODS

Planting materials and raising of crop

The experiment materials comprised genetically divers twenty three genotypes of bell pepper selected from various parts of the country. The experiment was laid out in a randomized block design with three replications during summer rainy season of 2008 at vegetable research block, GBPUA&T, Hill campus, Ranichauri (TG), Uttarakhand. Geographic position of the experimental site lies between 30° 15' N latitude and 78° 030' E longitude under mid hill zone of Uttarakhand, India. The mean monthly minimum and maximum temperature varied between 6.0° C- 16.6 °C and a 17.5° C-

23.7 °C, respectively during the cropping season. Row-to-row and plant-to-plant spacing was maintained at 60 cm and 45 cm, respectively. A single non-experimental row was planted on either sides of each plot so as to minimize environmental error due to border effect. All the recommended cultural practices were followed to raise the normal crop. Data were recorded on seventeen different traits viz., days to 50 percent flowering, days to first harvest, fruit length (cm), fruit diameter (cm), fruit girth (cm), number of fruits per plant, average fruit weight (g), fruit yield per plant (g), pericarp thickness (mm), number of lobes per fruit, pedicel length (cm), number of branches per plant, plant height (cm), leaf area (cm^2), number of pocking, harvest duration (days) and ascorbic acid content (vitamin C). For each observation, eight competitive plants has been chosen randomly.

Statistical analysis

The data recorded were analyzed statistically as per the model suggested by Gomez and Gomez (1983) for all the characters. The correlation between all the characters under study at genotypic and phenotypic level was estimated as per the method described by scarle (1961). Path coefficient was obtained according to the procedure suggested by Wright (1921) and elaborated by Dewey and Lu (1959).

RESULTS AND DISCUSSION

Analysis of variance

Analysis of variance revealed significant difference among the genotypes for all the traits indicating the presence of sufficient genetic variability in the germplasm and considerable scope for their improvement. Sufficient genetic variability for many of the horticultural traits studied in bell pepper and chilli had also been reported by earlier workers (Acharya et al. 2007; Vani et al. 2007 and Ukkund et al. 2007).

GCV, PCV, heritability and genetic advance

A perusal of the date (Table 1) revealed that the magnitude of PCV was higher than GCV for all the characters except number of lobes per fruit and leaf area. The estimates of PCV and GCV were high for fruit yield per plant, ascorbic acid content and average fruit weight, weight, moderate for days to first harvest, plant height and low for days to 50 percent flowering, fruit length, fruit girth, numbe of lobes per fruit, number of branches, number of fruit per plant and number of pickings. Mishra et al. (2005) also reported high phenotypic and genotypic coefficient of variations, for ascorbic acid content, fruit number per plant, fruit yield per plant and fruit length, respectively. PCV was high and GCV was moderate for harvest duration, where as pericarp thickness had moderate PCV and low GCV. High values of PCV and GCV indicated the existence of substantial variability, ensuring ample scope for their improvement through selection. These results further confirmed the findings of earlier researchers for fruit yield per plant (Vani *et al.*, 2007) and Ukkund *et al.* , 2007, for number of fruits per plant (Sreelatha kumary and Rajamony, 2002 and Mishra *et al.*, 2002), fro fruit length (Ibrahim et al. 2001), for average fruit weight (Sreelatha Kumary and Rajamony, 2002), for plant height and days to 50 percent flowering (Ibrahim *et al.*, 2001)

Heritability and genetic advance

Most off the traits studies (Table 1) had high heritability estimates thought they were moderate for fruit girth, harvest duration and number of branches and low for pericarp thickness and number of pickings. The heritability of the highest magnitude was noticed for average fruit weight (91.29%) and the lowest for pericarp thickness (16.35%). Thus, it indicated that larger proportion of phenotypic variance has been attributed to genotypic variance and reliable selection could be made for almost all the traits on the basis of phenotypic expression. High estimates of heritability in broad sense indicate that substantial improvement can be made using standard selection procedures. High heritability estimates for fruit yield per plant (Das and choudhary, 1999 and Sreelatha Kumary and Rajamony, 2002), average fruit weight (Das and Choudhary, 1999), number of fruits per plant (Sreelatha Kumary and Rajmony, 2002), days to 50 percent flowering and fruit length (Bhardwaj *et al.*, 2007), plant height (Ibrahim *et al.*, 2001 and Bhardwadj *et al.*, 2007) observed by earlier

Table 1. Mean performance of bell pepper genotypes in relation to different horticultural traits

Trait	Range	General mean ± SE (m)	Variance			Coefficient of variation %			Heritability (H2) %	Genetic advance	Genetic advance (% of mean)
			(PCV)	(GCV)	(ECV)	(PCV)	(GCV)	(ECV)			
Days to 50% Flowering	34.00-42.67	38.84±1.51	10.10	3.18	6.92	8.18	4.59	6.77	31.50	2.06	5.30
Days to first harvest	58.00-77.33	7.031±1.90	747.76	36.84	10.95	9.83	8.63	4.70	77.10	10.97	15.60
Fruit length	7.39-10.14	9.53±0.27	0.78	0.56	0.22	9.31	7.88	4.95	71.70	1.31	11.85
Fruit diameter	4.76-6.69	5.45±0.12	0.29	0.25	0.04	9.95	9.14	3.94	84.29	0.94	9.86
Fruit girth	17.10-20.25	18.43±0.525	1.70	0.88	0.82	7.10	5.11	4.92	51.86	1.39	7.54
No. of fruits/ plant	3.86-9.30	6.50±0.59	9.60	8.54	1.06	29.47	24.82	15.88	70.95	2.80	43.07
Average fruit wt. (g)	37.00-80.82	56.15±2.20	189.15	174.57	14.58	24.49	23.52	6.79	91.29	26.14	46.55
Pericarp thickness (cm)	0.33-0.50	0.39±0.29	3.00	0.0005	0.0026	14.30	5.78	13.08	16.35	1.88	48.20
No. of lobes/ fruit	3.000-4.00	3.37±0.99	0.129	0.10	0.029	9.63	10.89	5.09	78.10	0.59	17.50
Pedicel length (cm)	3.4-5.17	4.34±0.14	0.29	0.246	0.062	12.62	1.24	5.73	79.39	0.89	20.50
No. of branches/ plant	2.00-3.23	2.68±0.12	0.11	0.067	0.043	9.66	12.38	7.74	60.88	0.41	15.29
Plant height at first picking	43.74-63.84	52.82±1.79	40.07	30.41	9.66	11.98	10.44	5.88	75.88	9.89	18.72
Leaf area	14.53-41.68	22.06±1.23	42.67	38.09	4.58	27.93	29.56	9.68	89.24	11.99	54.36
No. of pickings	2.00-4.66	3.66±0.44	0.83	0.23	0.60	24.92	13.18	21.15	27.99	0.52	14.20
harvest duration	45.66-72.00	64.53±12.93	530.95	29.04	501.91	35.70	8.35	34.71	54.70	2.59	4.01
Ascorbic acid content (mg.)	83.18-187.80	131.65±6.41	1398.05	1274.46	123.59	27.98	26.68	8.44	90.89	68.98	52.39
Fruit yield/ plant	163.96-	404.30±31.13	2652.11	23611.85	2908.26	40.27	38.00	13.33	89.03	298.68	73.87

workers were in consonance with the present study. High heritability and high estimates of genetic advance (as percent of mean) were observed in case of fruit yield per plant (89.03) and 73.78%. ; leaf are (89.24 and 54.36%), and ascorbic acid content (90.89 and 52.39%). This suggested the presence of additive gene action (Panse, 1957) and hence these characters are likely to respond better to selection. High heritability and high genetic advance have also been obtained by many workers (Bhardwaj *et al.*, 2007)for fruit yield per plant, (Sreelatha Kumary and Rajamony, 2002) for average fruit weight, (Kataria et al., 1997 and Sreelathakumary and rajamony, 2002) for number of fruits per plant.

High heritability and moderate genetic advance was observed for average fruit weight. These results are in consonance with the findings of Ibrahim *et al.*, 2001 for fruit length and days to 50 percent flowering. High heritability along with low genetic advance were observed for days to first harvest, fruit length, fruit diameter, number of lobes per fruit, pedicel length number of branches per plant and plant height, which may be attributed to the non-additive gene effects and these traits can be improved through hybridization and use of hybrid vigour (Panse, 1957). Pericarp thickness (16.35 and 48.20) and number of pickings (27.99 and 14.20) showed low heritability

Associated with low genetic advance indicating the role of non additive genes for these traits suggesting thereby that their improvement could be achieved through heterosis breeding. Fruit yield per plant, number of fruits per plant, harvest duration, average fruit weight, plant height, number of lobes per fruit can be improved by selection, as these characters exhibited high to moderate genotypic and phenotypic coefficient of variation along with medium to high heritability and medium to high genetic advance.

Correlation coefficient of variation

A high positive significant correlation of days to 50 percent flowing and days to first harvest suggested (Table-2) that early flowering genotypes would be an appropriate selection criterion to get early marketable fruit yield. The number of fruits per plant had positive correlation with harvest duration and fruit yield per plant at genotypic level. Similar findings were notice by Mishra et al.(1998) and Ibrahim et al. (2001). Average fruit weight at marketable stage had significant positive relationship with numbe of pickings, ascorbic acid content and fruit yield per plant. Whereas, it had negative association with pedicel length and plant height at phenotypic level and fruit weight only at genotypic level. A significant positive correlation of fruit weight with pericarp thickness was also observed by Ben-Chaim and peron (2000) and their findings are in consonance with the present findings. Fruit length had positive association with plant height and number of fruits per plant at genotypic level . Hence, on the basis of correlation studies and their coefficient of determination, the selection for harvest duration , number of fruits per plant, average fruit weight, fruit diameter, fruit girth will be effective for isolating plants with higher fruit yield in bell pepper.

Number of lobes per fruit revealed significant positive association with harvest duration and number of branches. The character Pedicel length had significant positive correlation with plant height and significant negative correlation with harvest duration and number of pickings. Number of branches exhibited significant positive correlation with harvest duration and leaf area. While number of pickings showed significant positive association with ascorbic acid content and fruit yield per plant. Fruit yyiedl per plant had significant and positive association with fruit length, fruit diameter, number of fruits per plant and number of pickings both at phenotypic and gnotypic level. The results are in consonance with the findings of earlier researchers for number of fruits per plant (Ibrahim et al., 2001; Sreelathakumary and Rajamony, 2002; and bharadwaj *et at.*, 2007, fruit weight (Mishra et al., 1998; Sreelathakumay and Rajmony, 2002; an smith and Basavaraja 2005) and pericarp thickness . The significant

Table 2. Estimates of phenotypic (P), genotypic (G) and environmental (E) correlation coefficient for different horticultural traits in bell pepper

Trait		Days to 50% flowering	Days to first harvest	Fruits length	Fruit diameter	Fruit girth (cm)	No. of fruit/ plant	Average fruit wt. (g)	Pericarp thickness (cm)	No. of lobes/ fruits	Pedicel length (cm)	No. of branches	Plant height	Leaf area (cm²)	No. of pickings	Harves	Ascorbic acid (mg)	Fruit yield/ plant
Days to 50% flowering	P		0.14	-0.32	-0.12	-0.43**	-0.25	-0.16	0.29	0.24	0.23	-0.10	-0.36	0.85**-	0.18	-0.08	0.30	-0.16
	G		0.27	-0.42	0.65**	0.28	-0.31	-0.23	0.55**	0.36	0.29	-0.26	0.14	0.13	-0.40*	0.38	0.14	0.14
	E		0.34	-0.29	-0.14	0.12	-0.20	-0.14	0.22	0.16	0.22	0.14	-0.01	0.56**	-0.96**	-73**	0.10	-0.24
Days to first harvest	P			0.11	-0.63**	-0.26	-0.34	-0.58**	-0.14	0.13	0.41*	0.09	0.39	0.53**	-0.39	-0.13	-0.44*	-0.70**
	G			0.10	-0.75**	-0.29	-0.42	-0.69**	-0.40	0.10	0.48*	-0.04	0.57**	0.53**	-0.88**	-0.58**	-0.53**	-0.84**
	E			0.14	-0.12	-0.25	-0.11	-0.05	-0.13	0.24	0.17	0.40*	0.22	0.55**	0.52**	-0.34	-0.34	-0.23
Fruits length	P				0.90**	0.13	0.25	0.19	-0.12	-0.36	-0.35	-0.11	0.15	0.24	-0.18	-0.12	-0.16	0.50**
	G				0.04	0.25	0.30	0.21	-0.28	-0.43*-	-0.39	-0.16	-0.19	0.24	-0.29	-0.13	-0.21	0.75**
	E				0.41*	-0.51**	0.13	0.16	-65**	0.15	-0.24	-0.10	0.50**	0.29	-0.10	-0.19	0.34	0.56**
Fruit diameter	P						0.31	0.63**	0.32	0.31	-0.27	0.06	-0.45*	0.71**	0.22	2.23	0.34	0.66**
	G						0.34	0.72**	0.76**	-0.02	-0.35	0.01	-0.60**	0.11	0.33	0.16	0.38	0.78**
	E						0.21	-0.36	0.10	0.17	0.73**	0.20	0.10	-0.24	0.17	-0.31	0.59**	-0.84**
Fruit girth (cm)	P						0.31	0.18	0.02	-0.09	-0.04	-0.04	-0.03	0.02	0.08	0.05	0.08	0.29
	G						0.48*	0.25	0.59**	-0.17	-0.10	-0.22	-0.17	0.05	0.02	0.18	0.11	0.42*
	E						0.08	0.04	-0.23	0.44*	0.07	0.17	0.22	-0.07	0.12	0.03	0.01	0.04
No. of fruit/ plant	P							0.12	0.18	-0.02	-0.07	0.08	0.16	0.24	0.02	0.04	-0.13	0.62**
	G							0.10	0.21	0.09	-0.07	0.13	0.24	0.31	0.09	0.61**	-0.18	0.71**
	E							0.24	0.21	-0.10	0.18	0.08	-0.02	-0.08	-0.02	-0.14	0.06	0.42*
Average fruit wt. (g)	P								0.12	-0.12	-0.37	0.02	-0.52*	0.14	0.36	-0.03	0.37	0.65**
	G								0.23	-0.11	-0.44*	0.07	-0.61**	0.13	0.74**	-0.35	0.42*	0.68**
	E								0.12	-0.19	0.09	-0.17	-0.07	0.25	-0.03	0.18	-0.01	0.44*
Pericarp thickness (cm)	P									0.32	-0.06	0.27	-0.09	-0.08	-0.08	0.07	0.19	0.26
	G									0.67**	-0.12	0.71**	-0.55**	0.14	0.14	0.39	0.52**	0.61**
	E									0.18	-0.04	0.08	0.23	-0.05	0.05	0.04	-0.04	0.08
No. of lobes/ fruits	P										0.24	0.40*	0.03	0.31	0.01	0.07	-0.11	0.06
	G										0.33	0.46*	0.02	0.40	-0.16	052**	-0.11	0.08
	E										-0.09	0.27	0.07	-0.18	0.22	-0.08	-0.14	-0.05
Pedicel length (cm)	P											0.05	0.39	0.20	-0.40*	-0.27	-0.31	-030
	G											-0.08	-0.58**	0.23	-0.56**	-0.67**	-0.35	-0.37
	E											0.42*	-0.24	-0.08	-0.35	-0.29	-0.08	0.02
No. of branches	P												-0.02	0.40*	0.12	0.12	0.05	0.03
	G												-0.12	0.59**	0.31	0.73**	0.08	0.10
	E												0.18	-0.17	-0.05	-0.01	-0.03	-0.21
Plant height	P													0.08	-0.16	-0.12	-0.39	-0.34
	G													0.11	-0.67**	-0.96**	-0.50**	-0.41
	E													-0.05	0.34	0.14	0.21	-0.08
Leaf area (cm²)	P														0.07	0.13	-0.19	0.26
	G														0.09	0.31	-0.19	0.27
	E														0.11	0.20	-0.15	0.23
No. of pickings	P															0.05	0.37	0.37
	G															-0.08	0.73**	0.72**
	E															0.06	0.01	0.04
Harvest duration	P																0.03	0.12
	G																0.05	0.38
	E																0.06	0.12
Ascorbic acid (mg)	P																	0.29
	G																	0.31
	E																	0.09
Fruit yield/ plant	P																	
	G																	
	E																	

*,** Significant at P=0.05 and P= 0.01, respectively.

Table 3. Estimates of direct and indirect effect of different horticultural traits on fruit yield at phenotypic (P) and genotypic (g) levels in bell pepper

Trait		Days to 50% flowering	Days to first harvest	Fruits length	Fruit diameter	Fruit girth (cm)	No. of fruit/ plant	Average fruit wt. (g)	Pericarp thickness (cm)	No. of lobes/ fruits	Pedicel length (cm)	No. of branches	Plant height	Leaf area (cm^2)	No. of pickings	Harvest duration	Ascorbic acid (mg)	Correlation coefficient with Fruit yield/plant
Days to 50% flowering	P	**-0.00**	-0.03	0.01	-0.00	0.00	-0.12	-0.05	0.00	0.04	-0.00	0.01	0.00	0.01	-0.01	-0.00	0.00	-0.16
	G	**0.00**	-0.06	0.03	-0.02	-0.01	-0.29	-0.20	-0.05	-0.03	0.05	-0.07	-0.02	-0.04	-0.03	-0.02	0.01	-0.14
Days to first harvest	P	-0.0	**-0.21**	-0.00	-0.02	-0.00	-0.16	-0.18	-0.00	0.02	-0.00	-0.00	-0.04	0.00	-0.03	-0.00	-0.04	-0.70**
	G	0.16	**-0.23**	-0.08	0.32	-0.01	-0.36	-059	0.03	-0.08	0.09	-0.01	-0.09	-0.01	-0.07	-0.05	-0.06	-0.84**
Fruits length	P	0.00	-0.02	**-0.04**	0.00	-0.00	0.13	0.06	-0.00	-0.06	0.00	0.02	-0.01	0.00	-0.05	-0.00	-0.01	0.50**
	G	-0.25	-0.02	**-0.7**	-0.01	0.01	0.32	0.18	0.02	0.03	-0.08	-0.04	-0.03	-0.07	-0.02	-0.02	-0.02	0.75**
Fruit diameter	P	0.00	0.13	-0.00	**0.04**	-0.00	0.17	0.20	0.00	0.00	0.00	-0.01	0.05	0.01	0.01	-0.00	0.03	0.66**
	G	0.03	0.17	-0.03	**-0.42**	0.01	0.35	0.62	-0.07	0.01	-0.07	0.04	0.10	-0.03	0.02	0.05	0.04	0.78**
Fruit girth (cm)	P	0.00	0.05	-0.00	-0.00	**-0.01**	0.16	0.05	0.00	-0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.29
	G	-0.17	0.06	-0.02	-0.08	**0.05**	0.45	0.22	-0.05	0.01	-0.02	-0.06	0.02	-0.01	0.02	0.01	0.01	0.42*
No. of fruit/ plant	P	0.00	0.06	-0.01	0.01	-0.04	**0.53**	0.03	0.00	-0.00	0.00	-0.01	-0.01	0.03	0.00	0.00	-0.01	0.62**
	G	-0.19	0.08	-0.02	-0.05	0.02	**0.95**	0.09	-0.01	-0.08	0.01	0.03	-0.04	-0.10	0.08	0.06	-0.02	0.71**
Average fruit wt. (g)	P	0.00	0.12	-0.00	0.02	-0.00	0.06	**0.31**	0.00	-0.02	0.00	-0.00	0.05	0.02	0.03	-0.00	0.03	0.65**
	G	-0.14	0.16	-0.01	-0.31	0.01	0.10	**0.85**	-0.02	0.09	0.09	-0.02	0.10	-0.04	0.06	-0.03	0.05	0.68**
Pericarp thickness (cm)	P	0.00	0.03	0.00	0.01	-0.00	0.09	0.04	**0.08**	0.05	0.00	-0.04	0.01	0.02	-0.00	0.00	0.01	0.26
	G	0.033	0.09	0.02	-0.32	0.03	0.20	0.20	**-0.09**	-0.05	-0.02	0.20	0.09	-0.13	0.01	0.03	0.06	0.61**
No. of lobes/ fruits	P	-0.00	-0.02	0.01	0.00	0.00	0.00	-0.03	0.00	**0.16**	0.00	-0.07	-0.00	0.04	0.00	0.00	-0.01	0.60
	G	0.22	-0.02	0.03	0.09	-0.01	0.09	-0.09	-0.06	**-0.08**	0.06	0.13	-0.03	-0.13	-0.01	0.04	-0.01	0.08
Pedicel length (cm)	P	-0.00	-0.08	0.00	-0.01	-0.00	-0.00	-0.11	-0.00	-0.04	**-0.02**	-0.01	-0.04	0.02	-0.03	-0.01	-0.03	-0.30
	G	0.17	-0.11	0.03	0.15	-0.06	-0.07	-0.38	0.01	-0.02	**0.20**	-0.02	-0.09	-0.07	-0.04	0.06	-0.04	-0.37
No. of branches	P	0.00	-0.00	0.00	0.00	0.00	0.04	0.00	0.000	0.06	-0.00	**-0.17**	0.00	0.05	0.01	0.00	0.00	0.03
	G	-0.16	0.09	0.01	-0.06	-0.01	0.12	0.06	-0.06	-0.04	-0.01	**0.28**	0.02	-0.19	0.02	0.06	0.01	0.10
Plant height	P	0.00	-0.08	-0.00	-0.02	0.00	0.08	-0.16	-0.00	0.00	0.00	0.00	**-0.10**	0.01	-0.01	-0.00	-0.03	-0.34
	G	0.09	-0.13	-0.01	0.25	-0.01	0.23	-0.52	0.05	-0.01	0.11	-0.03	**-0.17**	-0.03	-0.05	-0.09	-0.06	-0.41
Leaf area (cm^2)	P	-0.00	-0.11	-0.00	0.00	-0.00	0.12	0.04	0.00	0.05	-0.00	-0.07	-0.00	**0.14**	0.00	0.00	-0.01	0.26
	G	0.08	-0.01	-0.01	-0.05	0.03	0.30	0.11.	-0.03	-0.03	0.04	0.16	-0.01	**-0.32**	0.07	0.02	-0.02	0.27
No. of pickings	P	0.00	0.08	0.00	0.01	-0.00	0.01	0.11	-0.00	0.00	0.00	-0.02	0.01	0.01	**0.08**	0.00	0.03	0.37
	G	-0.24	0.20	0.02	-0.14	0.01	0.08	0.63	-0.01	0.01	-0.11	0.08	0.11	-0.02	**0.08**	0.08	0.09	0.72**
Harvest duration	P	0.00	0.02	0.00	-0.00	-0.00	0.02	-0.00	0.00	0.01	0.00	-0.02	0.01	0.01	0.00	**0.04**	0.00	0.12
	G	0.01	0.13	0.01	-0.24	0.01	0.61	-0.30	-0.03	-0.04	-0.13	0.20	0.16	-0.10	-0.07	**0.09**	0.06	0.38
Ascorbic acid (mg)	P	-0.00	0.09	0.00	0.01	-0.00	-0.07	0.11	0.00	-0.01	0.00	-0.01	0.04	-0.02	0.03	0.00	**0.10**	0.29
	G	0.08	0.12	0.01	-0.16	0.06	-0.17	0.36	-0.04	0.09	-0.07	0.02	0.08	0.06	0.06	0.04	**0.01**	0.31

* Significant at P=0.05 and ** Significant at P=0.01, Rredidual effect P=0.1266, G=0.0271; Bold values indicate direct effects.

association fruit length, fruit diameter, number of fruits, number of pickings suggests that increase in any one of these traits may results in increase in fruit yield. These results are conformity with those reported by Sumith and Basavaraja (2005) and Bharadwaj *et al.*(2007), who advocated that the importance should be given to number of fruits per plant, fruit weight, number of primary branches, fruit length , fruit diameter and plant height during selection process because these characters contribute directly towards the yield.

Path analysis

Path analysis helps in partitioning correlation coefficients into direct and indirect effects of component characters in yield. Direct and indirect effects of all the traits on yield were computed at the genotypic level (Table 3). At genotypic level, number of fruits per plant had the highest positive direct effect on yield per plant followed by average fruity weight (0.85), number of branches (0.28), pedicel length (0.20) and harvest duration (0.90), while negative direct effect was observed for days to first harvest (-0.23), plant height (-0.17), pericarp thickness (-0.09) and fruit length (-0.07). High direct and positive effect of fruit weight (Mshra *et al.*, 2002), number of fruit per plant (Mishra *et al.*, 1998 and Mishra *et al.*, 2002) have also been reported by earlier workers. Average fruit weight had high positive direct effect along with indirect effect via days to first harvest, number of fruits per plant, number of lobes per fruit and pedicel length. The highly significant positive association of fruit diameter and number of pockings were the result of positive indirect effect of these traits via average fruit weight, number of fruits per plant and days to first harvest and also some individual direct effect of average fruit weight towards fruity yield per plant. Number of fruits per plant, besides having positive direct effect of high magnitude, had also positive indirect effects of considerable magnitude via days to first harvest, average fruit weight, number of picking and harvest duration. Similar findings have also been reported by Mishra *et al.* (1998) and Mishra *et al* (2002). The low magnitude of residual effect genotypic (0.071) level indicated that the traits included in the present investigation accounted for most of the variation present in the dependent variable. i.e. fruit yield per plant.

In view of the direct and indirect contributions of component traits towards fruit yield, selection on the basis of horticultural traits viz., average fruit weight and number of fruits per plant would be a paying preposition in the genotypes included in the study. Vani et al. (2007) also reported that number of fruits per plant and fruit diameter on yield per plant is the main contributors to yield in bell pepper.

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Effect of different mulching on growth and yield of potato crop at farmers field

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ABSTRACT

On farm trials were conducted to study the effect of different mulching on growth and yield of potato crop in 2005 and 2006 at the farmer's field in Coonoor, The Nilgiris district of Tamil Nadu. Mulching has positive effect on emergence. After 35 days of planting, highest emergence was 77.90% in mulching with white polythene sheet,82.75% in mulching with black polythene sheet during 2005 and 2006, respectively. After 45 days of planting, during 2005 and 2006, highest emergence was 96.98% in mulching with white polythene sheet and 99.75% in mulching with black polythene, respectively. In all trials lowest emergence was recorded in control. Growth rate was also better in all treatments where mulching was applied as compared to control at 60 and 75 days after planting. In the year 2005, at 60 days after planting, maximum growth rate (63.82%) was recorded in mulching with white polythene sheet, followed by 54% in mulching with black polythene and lowest (36.87%) in control. In 2006 trial, maximum growth rate (47.20%) was noted in mulching with black sheet followed by 42% in mulching with water hyacinth and minimum (30%) in control. Similarly, at 75 days after planting, all treatments where mulching was applied were found significantly different than control. Mulching also significantly affected the yield of potato crop. In the treatments where mulching was done with plastic sheet (black or white) yield was more than17 t/ha. In the treatment where water hyacinth mulch was applied, yield was 16.79 t/ha. However, highest yield(18.66 t/ha) was recorded in mulching with white polythene sheet, followed by 17.42,17.94 and 16.79 t/ha in mulching with black polythene, perforated black polythene and water hyacinth, respectively. Lowest yield (11.72 t/ha) was obtained in control. Application of white polythene resulted in the maximum net return and benefit : cost ratio among all the treatments.

Key words : Mulching, growth, yield, potato

The potato (*Solanum tuberosum* L.) belongs to the family Solanaceae is an important food crop in the world. It is regarded as the king of the vegetables. It is not unrealistic to say that very few food crops have the inherent capacity to meet the organoleptic demands of modern Indian Society as potato. In Coonoor, winter crop of potato is planted in January when temperature is low. This low temperature delays emergence while during crop development temperature starts rising day by day which affect crop production period adversely. To get better yield it is necessary to provide sufficient time period to this crop. This can be achieved by getting rapid germination. Mulching helps in better utilization of all the nutrients in the soil, help economic utilization of existing soil moisture and thus increasing the yield. Coling (1997) reported that plastic film mulches increased plant height, leaf area index, dry matter accumulation and tuber yield of potatoes. Sarma *et al.* (1999) planted potato cv. Kufri Megha on ridges and flat seed beds in various combinations with mulching and earthing up and reported that mulching with black plastic film increased the tuber yield significantly over normal planting method. However, under Coonoor conditions, very little information is available regarding the

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influence of different mulches on the growth and yield of potato. The present study was, therefore, undertaken to investigate the effects of different mulches on the growth and yield of potato.

MATERIALS AND METHOD

On farm trials were conducted during 2005 and 2006 at farmer's fields in the Coonoor taluq of the Nilgiris district in Tamil Nadu. The soil of the experimental field was sandy loam in texture with pH value of 6.9 having 145 kg available N, 15 kg available P and 186 kg k/ha. Five treatments combination consisting of Mulching with white polythene, Mulching with black polythene, Mulching with perforated black polythene, Mulching with water hyacinth and no mulching (control) were tested in randomized block design with three replications. Seed tubers (40 g size) of variety "Kufri Swarna" were planted at 60cm x 20cm distance in plots measuring 2.40 x 2.40 m on 5th and 10th May in 2005 and 2006, respectively. The land was prepared to its maximum tilth and organic manure @ 40 t/ha and 100:80:60 kg N, P_2O_5 and K_2O/ha, respectively were applied as basal dose at last ploughing of the experimental field and 100 kg N was top dressed at the time of earthing up. The crop was raised using all the recommended package of practices except mulching treatments. Different mulching materials were placed one week after planting. After 75 days of planting, mulches were removed and reapplied immediately after completion of earthing and top dressing of N. Data on emergence %age, growth rate (%), stems per plant and tuber yield was recorded and analyzed statistically for interpretation of result.

RESULTS AND DISCUSSION

Mulching has positive effect on emergence. In all the trials it was maximum in mulching with white polythene sheet. After 35 days of planting, highest emergence was 77.90% in mulching with white polythene and 82.75% in mulching with black polythene sheet during 2005 and 2006, respectively (Table 1). After 45 days of planting, during 2005 and 2006, highest emergence was 96.98% in mulching with white polythene and 99.75% in mulching with black polythene, respectively. The lowest emergence was recorded in control (Table 1). This reflects that how much mulching can accelerate emergence. Wierzbicka (1995) also reported that mulching increased emergence by 5 days. The combination of pre-sprouting and mulching was most profitable. These results are also correlated with the findings of Ping *et al.* (1994). They reported that mulching on the ridges increased the soil temperature, improved the soil characteristics and improved early plant growth. This leads to early maturity and higher tuber yield.

Growth rate was also higher in all

Table 1. Effect of mulching on emergence and growth rate of potato

Treatment	Emergence (%)				Growth rate (%)			
	2005		2006		2005		2006	
	35 DAP	45 DAP	35 DAP	45 DAP	60 DAP	75 DAP	60 DAP	75 DAP
Mulching with white polythene sheet	77.90	96.98	82.00	98.00	63.82	72.90	37.00	79.90
Mulching with black polythene sheet	53.00	95.36	82.75	99.75	54.00	62.53	47.20	78.00
Mulching with perforated black polythene sheet	40.10	94.10	80.12	98.85	45.90	58.92	38.12	66.45
Mulching with water hyacinth	71.16	94.00	60.15	96.00	40.00	61.00	42.00	61.00
Control	9.00	91.00	4.95	67.25	36.87	59.98	30.00	44.52
C D at 5%	19.07	6.72	13.78	9.65	5.25	6.34	13.90	9.94

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treatments, where mulching was applied as compared to control at 35 and 45 days after planting (Table 1). During 2005 and 2006, highest growth rate was recorded in mulching with white polythene followed by mulching with black polythene. In the year 2005, 60 days after planting, maximum growth rate (63.82%) was recorded in mulching with white polythene followed by 54.00% in mulching with black polythene and lowest (36.87%) in control. In 2006 trial maximum growth rate (47.20%) was recorded in mulching with black polythene followed by 42% in mulching with water hyacinth and minimum (30%) in control. Similarly, at 75 days after planting, mulching with white polythene and mulching with black polythene were found significantly different than other treatments. However, all treatments where mulching was applied were found significantly different than control at 75 days after planting. Mulching has significant effect on yield of potato crop. In the treatments where mulching was done with plastic sheet (black or white), yield was more than 17 t /ha. This might be due to more congenial soil temperature, which resulted in better tuberization. In the treatment where water hyacinth mulch was applied, yield was 16.79 t/ha (Table 1). However, highest yield (18.66 t/ha) was recorded in the treatments where white plastic sheet was applied, followed by 17.42, 17.94 and 16.79 t/ha in mulching with, black, perforated black polythene and water hyacinth, respectively (Table 1). The highest yield obtained with white plastic sheet may be due to more favourable temperature for better emergence and good growth resulting in bigger tuber size. Ruiz *et al.* (1999) mulched potatoes cv. Spunta by transparent, white or black polythene of 25 um thickness, or co-extracted black and white plastic of 50 um thickness in a field experiment during 1993-95 in Spain and reported that the use of white plastic promoted optimum root temperature for plant growth (23-27 °C) and resulted in the greatest efficiency of nitrogen utilization and greatest tuber yield. Highest root temperature caused by black plastic (>31 °C) depressed nitrogen metabolism as well as yield. Lowest yield (11.72 t /ha) was obtained in control. Overall increase in yield was 59.21% in mulching with white polythene, 48.63% in black polythene, 53.07% in perforated black polythene and 43.2% in water hyacinth over control (Table 1). These results are also supported by the findings of Khalak and Kumaraswamy (1993). They reported that tuber yield was increased from14.3 t/ ha with no mulching to 16.7 t /ha with straw and 18.2 t /ha with plastic mulches. Momirovic *et al.* (1997) reported that mulch application resulted in a significant decrease in soil temperature in the root zone and the conservation of soil moisture. The number and weight of tubers and tuber yield in

Table 2. Effect of mulching on yield of potato

Treatment	Yield (t/ha)			Difference (t/ha) over control	% increase in yield over control
	2005	2006	Mean		
Mulching with white polythene sheet	18.78	18.54	18.66	6.94	59.21
Mulching with black polythene sheet	16.16	18.68	17.42	5.70	48.63
Mulching with perforated black polythene sheet	17.83	18.06	17.94	6.22	53.07
Mulching with water hyacinth	17.39	16.20	16.79	5.07	43.25
Control	14.94	8.50	11.72	-	-
C D at 5%	4.19	2.74		-	-

the mulch treatment were significantly greater in both years than on plots without mulch. From the results it is concluded that mulching has very good effect on emergence. Plastic sheet enhances temperature and accelerates the germination.

Application of white polythene resulted in the maximum net return and benefit : cost ratio among all the treatments, while lowest net return and benefit : cost ratio was recorded under control.

Table 3. Economics

Treatments	Gross return (Rs./ha)	Cost of production (Rs./ha)	Net return (Rs./ha)	Benefit: Cost Ratio
Mulching with white polythene sheet	50382	9000	42128	5.59
Mulching with black polythene sheet	47034	9000	38834	5.22
Mulching with perforated black polythene sheet	48438	9000	40238	5.38
Mulching with water hyacinth	45333	8400	37533	5.39
Control	31644	7000	24644	4.52

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Influence of nitrogen and sulphur on seed yield and quality of canola oil seed rape, *Brassica napus* L.

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There is not only chronic shortage of edible oils in the country; its demand is further increasing at the rate of about 4-6 per cent annum. Indian mustard (*Brassica juncea* L.) and oilseed rape (*Brassica napus* L.) are important oilseed crops of rapeseed-mustard (*Brassica* sp.). The oil of conventional rapeseed-mustard cultivars of India contains nutritionally undesirable; long chain fatty acids, mainly eicosenoic and erucic acids. The protein rich seed meal obtained after oil extraction is a valuable animal feed but contains higher amount of glucosinolates in conventional cultivars. Owing to health benefits of canola oilseed rape, its demand is likely to increase in future. Nitrogen (N) and sulfur (S) play multiple roles in oilseed crops (Ahmad and Abdin, 2000). The availability of one nutrient, in addition to its direct role in promoting growth and yield, regulates the activity of another (Barney and Bush, 1985). Indian soils are generally deficient in N and deficiency of S is becoming more widespread mainly due to adoption of double/multiple cropping systems, increasing cultivation in light textured soils, use of S-free fertilizers and use of canal water for irrigation.

Since N and S are major nutrients influencing the yield and quality of oil and seed meal, their influence on the yield and quality of oil and seed meal of canola quality oilseed rape was studied. The experiment was conducted at the research farm of Department of Plant Breeding and Genetics, Punjab Agricultural University, Ludhiana in rabi 2004-05. Sandy loam (Typic Ustochrepts) soil of the experimental field was low in organic carbon (0.30%), rich in available phosphorus (28.0 kg/ha), available potassium (217 kg/ha) and medium in available S (12 ppm). Combinations of 3 doses of nitrogen (100, 125 and 150 kg/ha) and 3 doses of sulfur (20, 40 and 60 kg/ha) were replicated thrice in randomized complete block design.

Canola oilseed rape hybrid PAC 401 was sown on November 25, 2004 in 45 cm apart rows seed rate of 3.75 kg/ha. Plot size of 14.4 m^2 was maintained to accommodate eight rows each of 4 metre length. Phosphorus (30 kg P_2O_5/ha) and half dose of N as per treatments were applied before sowing. The required dose of S as per treatments was also applied at sowing through gypsum (15.5% S). After completion of thinning/ gap filling and application at first irrigation the remaining amount of N was top dressed at about 35 days after sowing (DAS). The crop was manually harvested on April 11, 2005. Statistical analysis was done by factorial randomized complete block design. The seed samples were collected randomly from the produce of whole plot. Nuclear magnetic Spectroscope (Newport Analyzer model MK 11A) employing non-destructive method of oil estimation was used to determine oil content in the whole seed. The fatty acid composition of oil (Applequist, 1968) and glucosinolate contents (Thies, 1982) in seed were estimated using standard procedures.

Application of 125 kg N/ha resulted in 6.3 per cent higher seed yield than 100 kg N/ha (Table 1). Likewise, significant response to S application was discerned up to 40 kg/ha, which contributed 19.4 per cent more seed yield over 20 kg S/ha. Similar trend was noticed for Stover yield (Table 1). Improvement in yield accrued from increase in number of primary branches and siliquae per plant due to application of N and NS. Influence of S was more pronounced than N. Similar increases in seed yield of canola have been reported with application of N

(Momoh *et al.*, 2004) and sulphur (Ahmad *et al.*, 2001). With 100 or 125 kg N/ha, application of 40 kg S/ha resulted in significantly higher seed yield over 20 kg S/ha (Table 2). The highest seed yield was obtained with 125 kg N + 60 kg S/ha (1728 kg/ha) which was at par with 125 kg N + 40 kg S/ha (1708 kg/ha), 150 kg N + 40-60 kg S/ha (1625-1720 kg/ha) and 100 kg N + 40 kg S/ha (1646 kg/ha) but conspicuously higher than other combinations of N and S. Thus application of 1525 kg N with 40-60 kg S/ha resulted in 28.9-30.4 per cent higher seed yield than 100 kg N + 20 kg S/ha (1325 kg/ha). Both N S after enzyme activity in their assimilatory pathways (Barney and Bush, 1985; Bell *et al.*, 1995; Ahmad *et al.*, 1999) and interact in such a way that inadequacy of one reduces the uptake and assimilation of other (Zhao *et al.*, 1999). Effect of N and S on oil content was non significant (Table 1).

Application of N and S failed to significantly alter the fatty acid composition of oil (Fig. 1). The palmitic and oleic acid marginally increased up to 150 kg N/ha, whereas, such trend for lioleic and linolenic acid was observed up to 125 kg/ha. However stearic, eicosenoic and erucic acid content showed decreasing trend with increasing N application. Similar trend was discerned for S application except eicosenoic acid which was highest with 40 kg S/ha.

Increase in N from 100 to 125 kg/ha significantly reduced the glucosinolate content in seed meal, which leveled off with further increase in N (Table 3). These findings are in

Table 1.Influence of application of nitrogen and sulphur on yield attributes, seed yield, stover yield and oil content of oilseed rape

Doses of nutrients	Plant height (cm)	Length of main shoot (cm)	Primary branches per plant	Number of silique per plant	Seed yield (kg/ha)	Stover yield (kg/ha)	Oil content (%)
Nitrogen (kg/ha)							
100	130	62.0	4.4	157	1517	4944	41.1
125	130	62.3	5.0	179	1613	5232	41.2
150	133	64.3	4.9	170	1595	5388	40.9
LSD (P=0.05)	NS	NS	0.4	18	NS	NS	NS
Sulphur (kg/ha)							
20	133	61.3	4.6	163	1389	4839	41.6
40	130	64.3	4.8	170	1660	5309	41.0
60	130	63.0	4.9	173	1676	5416	41.0
CD(P-0.05)	NS	NS	NS	NS	185	377	NS

Table 2.Interactive effect of graded doses of nitrogen and sulphur on seed and stover yield of oilseed rape

Doses of nitrogen (kg/ha)	Doses of sulphur (kg/ha)					
	20	40	60	20	40	60
	Seed yield (kg/ha)			Stover yield (kg/ha)		
100	1325	1646	1580	4806	5144	4881
125	1403	1708	1728	4811	5247	5638
150	1440	1625	1720	4900	5535	5728
CD (P=0.05)	302			NS		

agreement with Momoh *et al.* (2004). Similarly increase in S from 20 to 40 kg/ha caused significant reduction in glucosinolates. Zhao *et al.* (1997) observed that S supply decreased glucosinolates in rapeseed. With lower dose of N, glucosinolate content increased with increasing S application, whereas it decreased when both N and S were increased.

Thus application of 125 kg N + 40 kg S/ha significantly increased seed yield, reduced erucic acid in oil and glucosinolates in seed meal.

Table 3. Interactive effect of graded doses of nitrogen and sulphur on glucosinates content (mmole/ g defatted seed meal)

Doses of nitrogen (kg/ha)		Doses of sulphur (kg/ha)			Mean
		20	401	60	
100		12.63	15.0	16.26	14.63
125		16.20	11.68	10.68	12.85
150		16.94	10.90	10.55	12.80
Mean		15.26	12.53	12.50	
CD (P=0.05)	N: 1.53	S: 1.88	N X S: 3.26		

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Effect of sowing method and date of sowing on germination and yield of cotton (*Gossypium hirsutum*) irrigation with saline water

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Low yield of crops grown under saline conditions are usually ascribed to poor germination and crop stand at early seeding stage. The poor germination, in turn, is due to high salt concentration where seed are placed in the seed bed (Hoffman, 1982). Thus it is necessary to develop appropriate planting techniques which are iikely to provide relatively lower salinity around the germinating seeds. Several workers (Chauhan *et al.*, 1987) showed that various practices such as bed shape and irrigation management can gready enhance salt content during the germination period.

Field experiment was conducted at salinity research project (ICAR) R.B.S College, Bichpuri, Agra during *kharif* 2005 under semi-arid sub tropical climatic conditions on light fextured (clay 14%) normal soil. pH 8.5 and EC 9 ds m^{-1} The treatments were comprised three date of sowing D_1 15 May, D_2 30 May and D_3 15 June and two levels of irrigation water (BAW) best available water and EC 8 ds m^{-1} and two method of sowing flat (traditional method) and bed sowing method. The full dose of P_2O_5 and K_2O were applied time of sowing and one third dues of N was at the time of sowing and two third doses of N was applied two split at top dressing at 45 and 90 days of sowing. The irrigation water was applied in flat sowing 7 cm depth and bed sowing 4 cm depth. The four-tagged plant

Table 1. Effect of date of sowing, method of seeding and salinity levels on yield and ancillary characters of cotton

Treatments	Germination (%)	Plant height (cm) 150DAS	Monopodia plant	Sympodia plant	Bolls plant 135 DAS	Seed cotton yield (q/ha)
Date of sowing						
D_1	63.6	102.9	13.2	14.0	33.7	29.8
D_2	58.9	101.5	10.4	11.4	31.8	28.4
D_3	56.1	100.2	9.0	10.4	29.1	23.6
CD (P=0.05%)	2.8	1.3	0.5	0.6	0.6	1.2
ECiw levels dSm^{-1}						
BAW	60.0	101.8	11.0	12.4	32.8	31.8
8	58.4	100.2	10.7	11.5	30.3	22.6
CD (P=0.05%)	2.3	1.0	0.4	0.4	0.5	1.0
Method of sowing						
Flat	57.9	100.6	10.0	10.9	29.4	23.9
Bed	61.0	103.1 .	11.7	13.1	33.7	30.6
CD (P=0.05)	2.3	1.0	0.4	0.4	0.5	1.0

observed in 30 days interval all observations. The cultivar 'MECH-911' cotton was sown at three dates and harvested on 20 January 2006.

The germination (%) in cotton crop was maximum (63.6%) in 15 May sowing and lowest (56.1%) in 15 June. The ECiw levels singificantly reduced the gemination in ECiw 8 dSm^{-1} compared with BAW. The method of sowing one germination significantly higher in flat method of sowing.

Results (Table 1) indicated that different date of sowing had significant effect on yield, though 15 May sowing giving the highest yield, which was 4.7% and 20.8% more than 30 May and 15 June date of sowing. The sowing on 30 May significantly had more yield 16.9% than 15 June date of sowing. However, the maximum number of boll, plant height, monopodia/plant, sympodia/plant were significantly higher in 15 May date of sowing.

The use of saline water in irrigation significantly higher attributes in BA W compared with EC 8 dSm^{-1}. The grain yield so significant in salinity water the BAW 28.9% more yield than compared with EC 8 dSm^{-1}.

The method of sowing also differ significantly in all attributes. The bed sowing method increased the seed yield by 21.8% than flat sowing method (Chauhan, 2001) reported similar results.

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Effect of conjunctive use of tubwell canal water on sunflower

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Surface water resources in arid and semi-arid tracts of Uttar Pradesh are insufficient and single most important source of supplemental irrigation in this area is ground water. But unfortunately, the quality of under ground water is very poor high RSC. The large scale and indiscriminate use of this water causes sodicity of soil which have sufficient quantity of exchangeable sodium to deteriorate the soil stricture and interfere plat growth adversely besides some nutritional disorders due to high pH. Under such situation, crop production can be sustained by conjunctive use of tub well/canal water with out deteriorative effect on soil. The present investigation was carried out effect of conjunctive use of tubwell/canal water on sunflower irrigated with high RSC water.

Field experiment was conducted during summer season of 2003-04 at experimental farm R.B.S.College, Bichpuri, Agra. Nine treatments combinations consisting T1, all canal, T2, one canal: one alkali, T3 two canal: two alkali : two canal, T4, two alkali: two canal: two alkali, T5, four alkali: two canal, T6, potato (canal) : sunflower (alkali), T7, mixing (one canal + two alkali), T8 mixing (two canal + one alkali) and T9 all alkali were tested in randomized block design with three replications. The soil was sandy loam with electrical conductivity 1.4-4.5 dS m^{-1}, PH 8.0-8.5, available nitrogen 192 kg/ha, available P_2O_5 16.5 kg/ha, available K_2O 172 kg/ha and organic carbon 0.32% sunflower MSFH-

Table 1. Yield and yield attributing character of sunflower affected by different irrigation modes

Treatments	No. of grain/ head	Diameter of head (cm)	Seed wt./ head	1000 grain weight (g)	Seed yield (q)	Oil content (%)
T1 CW	403	11.8	12.9	31.2	15.4	43.3
T21CW: lAW	369	11.4	11.1	27.7	14.4	42.2
T32CW: 2AW: 2CW	348	11.1	10.1	27.2	12.8	41.9
T42AW: 2CW:2AW	310	10.8	8.8	25.4	10.1	40.6
T54AW: 2CW	293	10.4	8.8	23.8	6.2	40.4
T6 P (CW): S (AW)	344	10.6	8.0	24.2	10.2	41.2
T7 Mixing (lCW+2AW)	351	10.7	9.6	26.7	10.9	41.8
T8 Mixing (2CW+1AW)	355	11.3	10.6	28.1	12.4	42.2
T9AW	264	10.1	6.7	23.0	4.9	40.3
CD (P=0.05)	23.8	1.3	1.4	2.7	1.9	1.4

17 was sown on March 18 at row spacing 45 cm. The recommended dose of fertilizer given at the time of sowing. The irrigation water having RSC 15 me 1^{-1}.

The yield attributes like no. of seed/head diameter/head, seed weight/head and test weight (g) significantly higher in all canal (T1) and lowest in all alkali (T9) Freatments. The other treatments i.e. ICW: IAW, 2CW: 2AW and mixing (2CW+1AW) were at par for yield attributes (Table 1). The seed yield of suntlower statistically higher in T1 (15.4 q) and lowest in T9 (4.9 q). The other treatments a use of alkali water in later stage they give at par yield i.e. 1CW: lAW, 2CW: 2AW: 2CWand mixing (2CW+1AW). The other modes 2AW: 2CW: 2AW, P (CW): S (AW) and mixing (ICW+2AW) produced at par yield the same results given by Naresh et al (1992a) and (1992b). The oil content per cent was higher in T1 and lowest in T9 treatment and other treatments between these limits and 2-3% reduction in oil content per cent.

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Yield and economics of vegetable pea- wheat -maize cropping system in Central U.P.

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India is a leading vegetable producing country in the world. Presently vegetable cultivation occupies 6.09 million hectare area with an annual production of 84. 8 million tones. Due to the burgeoning population of the country, it is estimated that by 2020, the country's vegetable demand would be around 135 million tones. To achieve this target, it is sine qua non to integrate the various technologies of vegetable production (Rai and Pandey, 2006). Simultaneously our food grains requirement would be about 240 million tones by that time. This would necessitate massive efforts for increasing also that the food grains production in country. The high intensity cropping sequences in agriculture-developed area may play an important role. The sequences involving two or more food grain crops with inclusion of legumes are of paramount importance as these will maintain the soil. The input requirements of such sequences will go down, as the leguminous crop require lesser amount of fertilizer and irrigation

Studies were carried out at the experimental farm C.S.A University of Agriculture and Technology, Kanpur (UP) during 2004-06 on sandy loam soil. The vegetable pea (Arkel), wheat (Raina) and maize (Azad Uttam) were grown in rotation fixed plots. The treatments were applied in vegetable pea crop only, and their residual effect are studied on succeeding wheat crop grown in the sequence. Treatments consisted three date of sowIng D_1 (30 September), D_2 (10 October) and D_3 (20 October) and five levels of nitrogen N_0 (Control), N_2 (20 kg/ha, N_3 (40 kg/ha) N_4 (60 kg/ha and N_5 (80 kg/ha. The full does of P and K was applied at the time of sowing.

The results (Table 1) revealed that pod yield of pea produced highest of 54.3 q/ha which was found 4.3% and 8% higher than the pod yields obtained in 10th October and 20th October sowing, respectively. The pooled data for the two years for pod yield in vegetable pea clearly indicated that N80 kg/ha produced highest pod yield of 54. 8 q/ha which was calculated to be 0.8, 2.9,6.8 and 7.2% higher than pod yield obtained at N60, N40, N20 and N_0 kg/ha of nitrogen respectively. The wheat crop produced maximum yield (36.6 q/ha) on 30th September date of sowing which was found 3 and 5.2% higher than 10th October and 20th October sowing. The residue of N_0 kg/ha being at par with N60 and N40 levels significantly higher grain yield of wheat than N20 and N40 levels. The seed yield of maize did not differ significantly in all the treatments like-wise date of sowing and N levels. The net profit and B:C ratio of the system was obtained significantly maximum under pea sowing on 30th September while it was minimum last pea sowing on 20th October. In pooled means nrst pea sowing earned maximum of Rs. 50,112/ha which was found Rs. 12,045/ha and Rs. 19,435/ha more than the net profit with second significantly up to N60 levels where Rs. 42,013/ha could be earned and this value was found Rs. 1,427/ha, 3,341 and 7,586 more than the net profit values at N40, N20 and N0 levels reapectively. The earlier sowing of pea attained significantly maximum B:C ratio which on pooled basis was recorded 0.94. It was found 0.22 and 0.36 unit more than under second and last sowing. The N levels improved B:C ratio up to highest of N80 but increase beyond N20 level was not foUnd significant in any case. The N levels at N40 and above attained significantly higher ratio (between 0.73 and 0.79) than only control the some results confirmed by Rai *et al.* (2005).

Table 1. Effect of yield and economics in different treatments

Treatments	Pod yield of pea (q/ha)	Grain yield of wheat (q/ha)	Seed yield of maize (q/ha)	Net profit of the cropping system	B:C ratio of the cropping system
Date of sowing					
DI	50.3	36.6	32.3	50.112	0.94
D2	52.1	35.6	32.3	38.077	072
D3	54.3	34.8	32.0	30.337	0.58
CD (P=0.05)	0.7	0.7	NS	0.358	0.09
Nitrogen levels (kg ha)					
NO	47.6	34.1	32.1	34.427	0.65
NI	51.3	35.2		38.672	0.73
N2	53.2	35.8	32.3	40.586	0.76
N3	54.3	36.5	32.1	42.013	078
N4	54.8	36.8	32.3	42.446	0.79
CD (P=0.05)	1.4	1.5	NS	0.894	0.08

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Response of wheat (*Triticum aestivum*) cultivars to potassium application

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It is estimated that harvested crips remove about 9-10 million tones more $N+P_2O_5 + K_2O$ every year than the total additions through fertilizers in India (Trandon, 1955). Due to over exploitation of the soil reserves and the introduction of high yielding varieties of crops, all crops started responding to fertilizers. It is well known that crop varieties differ in then nutrient reqirements. Therefore, the present investigation was aimed to response of wheat cultivars to potassium application.

The field experiment was conducted in RBD design with three replications at the Research Farm of the Department of Soil Science, RB. S. College, Bichpuri, Agra (U.P.) during *rabi* season of 2006-07. The experiment soil was sandy loam having pH 8.0, ECe 0.19 dS/m, organic carbon 0.032%, available N 192 kg/ha, available P 16.4 kg/ha and available K 172 kg/ha the treatments comprised of two wheat varieties (Raj. 3765 and HD. 2329), five levels of K (0,30,60,90 and 120 kg/ha). Half dose of N and full does of P and K was appli8ed at the time of sowing the remaining half does of k was applied after first irrigation at CRi in all the treatments.

All the yield attibtites, grain and straw yield were recorded. The wheat crop was sown on November 15, 2006 at the rate of J 25 kg/ha. sowing was done in the furrows the furrow were opened 20 cm apart from one another. The crop harvested at maturity on March 25, 2007. The other cultural practices may be done as per crop recommendation.

The results indicated that the growth and yield attributes of wheat with incresing levels of potassium application. The maximum plant height (67.8 cm), effective tilters/m row length

Table 1. Yield and yield attributing characters of wheat as influenced by variety and potassium levels

Treatments	Plant height (cm)	Effective tillers/m row length	Spike length (cm)	Grain/ spike	1000 grain weight (g)	Grain yield (q)	Straw yield (q)
Varieties							
Raj. 3765	66.5	63.7	6.9	41.8	41.7	39.	60.4
HD. 2329	68.1	65.2	7.5	43.5	42.9	41.	62.7
CD at 5%	1.2	1.1	0.5	0.9	0.9	1.3	1.2
Potassium levels (kg/ha)							
0	3.1	58.2	6.2	36.2	35.3	37.5	57.9
30	61.1	60.4	6.8	38.2	36.8	38.8	59.5
60	65.2	62.3	7.1	39.5	38.9	40.0	61.8
90	66.3	63.2	7.3	41.3	40.2	42.0	63.9
120	61.8	65.7	7.5	44.5	41.8	42.5	64.4
CD at 5%	1.8	1.7	0.8	1.2	NS	NS	

(65.7), spike length (7.5cm), grain/spike (44.5) and test weight (41.8g), seed yield (42.5q) and straw yield (64.4q) of wheat was recorded under K 120 kg followed by K 0 kg (Table 1). The seed and straw yield of wheat were increased appreciably with increasing doses of K. The application of K 120 kg and K 90 kg were statistically at par in terms of seed yield, but application of K 120 kg was significantly superior to rest of the treatments in straw production (64.4 q) of wheat. The minimum seed yield (37.5 q), straw production (57.9 q) was recorded in control plots.

The variety of wheat HD 2329 had significantly higher yield attributing characteristics i.e. plant height, no. of shoot, spike length, no. of grain/spike and test weight was maximum in HD 2329 compared with Raj. 3765. The grain land straw yield were also significant in wheat variety. The maximum grain and straw yield were found in HD 2329 (41.2 q) and (62.7 q) compared with Raj. 3765 (39.4 q) and (60.4 q). The same results were giving by Singh and Singh. The same results were giving by Singh and Singh (1998), Tiwari *et al.* (1985) and Shivay *et al.* (2002).

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Effect of different fertilizer levels on mustard (*Brassica compestris*) varieties under saline irrigation

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In our country due to sharply increasing population the scarcity of edible oils has become the major problem. Indian mustard (*Brassica juncea* L.) is an important oil seed crop of arid and semi arid parts of India. In the Indo-Gangetic plains of Northern India, this crop is grown on about 3.8 million hectare, mainly as a dry land crop. Because of water shortages at critical growth stages, substantial field loss occurs. The crop may be unable to complete its life cycle because of failure of winter rains and the limited moisture carrying capacity of the course.

The field experiment was conducted at ORP, saline water project (ICAR), RBS College, Bichpuri, Agra on farmer field Karanpur, Mathura (UP) during the winter season 2007-05. The soil was sandy loam containing 1930.6 kg/ha, available N. 185 kg/ha, available P_2O_5 and 180 kg/ha available K. There were five varieties of mustard i.e. CS-61. SAL-7. Kranti, SAL-9 and CS-52 and four levels of fertilizers 75% extra RDF. 125% extra RDF and 150% extra RDF (Table 1). It was laid out in factorial RBD design with four replications. The mustard varieties was sown in row at 45 cm apart using 5 kg seed/ha on 18 October 2004. The mustard seed was received from NRC rape seed and mustard. The crop as thinned 15 days after sowing to maintain a plant-to-plant spacing of 10 cm. The full dose of P_2O_5 and K_2O and half in N was applied uniformly in whole field. The remaining half N was top dressed after the first irrigation. The irrigation water of farmer tube well haying EC1w 11.0 dsm^{-1}.

Table 1. Yield and yield attributing characters of mustard as affected by different treatments

Treatments	No. of silequa/plant	No. of seed/ silequa	Length of silequa	Seed yield/ plant	Yield (q/ha)
Varieties					
CS-61	231.8	11.8	4.2	11.8	15.4
SAL-7	208.7	8.9	3.7	10.9	12.9
Kranti	236.1	12.6	4.5	13.7	15.8
SAL-9	217.8	12.8	4.3	12.6	14.7
CS-52	221.9	11.8	4.1	12.4	13.9
CD (P=0.5)	12.5	0.4	0.3	1.2	1.3
Fertilizer levels					
75% RDF	208.3	10.0	3.7	10.5	12.0
RDF	225.3	11.5	4.2	12.6	15.0
125% RDF	228.3	12.2	4.3	12.9	15.3
150% RDF	230.6	12.5	4.4	12.1	15.7
CD (P=0.05)	11.2	0.4	0.3	0.9	1.1

RDF: 120 kgN, 40 kg P_2O_5 and 40 kg K_2O

The yield and yield attributing characters are presented in Table 1. It is clear indicated that number of silequa plant, no. of seed silequa plant, length of silequa (cm) and seed yield plant increased with increasing the fertilizer levels and significant increase in RDF 15 and 150% fertilizer level.

In mustard varieties the higher yield was obtained in Kranti (155.5 q^{-1}) and lowest in SAL-7 (12.9 q^{-1}). Among the fertilizer levels yield declined significantly with 75% recommended fertilizer levels. However, other fertilizer levels RDF (20 kg N, 40 kg P_2O_5 and 40 kg K_2O). 125% RDF and 150 RDF showed yield at par. The same trends were also observed that Patel *et al.* (1998); Agamal and Gupta (1991); Tomar *et al.* (1996); Arahamar *et al.* (1996); Tripathi and Tripathi (2003) also reported similar findings.

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Yield attributes and yield of okra [*Abelmoschus esculentus* (L.) Monech] as influenced by integrated nutrient management and its residual effect on radish (*Raphanus sativus* L.) in arid western Rajasthan

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ABSTRACT

A field experiment was conducted during *Kharif* season 2004 and residual radish crop during winter season of 2004-05 to find out the effect of vermicompost levels and fertilizers combinations (NPK) on yield attributes and yield of okra [*Abelmoschus esculentus* (L.) Monech] and its residual effect on radish *Raphanus sativus* L.). Application of increasing levels of vermicompost up to 6 t ha^{-1} significantly enhanced the length of fruits, width of fruits, fresh weight of fruit, dry weight of fruit at first picking, number of picking and yield of okra. After that, the effect of 9 t ha^{-1} was found to be at par with 6 t vermicompost ha^{-1}. However, the increment in days taken to flower initiation, days taken to fruit initiation, days taken to first fruit picking and moisture content in fruits at first picking was found statistically non significant due to application of vermicompost in okra crop. Further, root length, root width, root weight and root yield of residual crop radish also increased significantly with increasing levels of vermicompost up to 6 t ha^{-1} applied in preceding crop. Further an application of fertilizer combinations up to 60:30:30 kg NPK ha^{-1} significantly enhanced the length of fruits, width of fruits, fresh weight of fruit, dry weight of fruit at first picking, number of picking and yield of okra. In residual crop radish root length, root width, root weight and root yield also increased significantly with increasing levels of fertilizer combinations up to 30:15:15 kg NPK ha^{-1} applied in preceding crop.

Key words : Fertilizer, okra, radish, vermicompost, yield attributes

The world's arable land resources are finite and there is not much scope for significantly expending the area of land under cultivation. Hence, most of the increase in agricultural production will have to be obtained through increased productivity from the existing agricultural land. This can be achieved by fertilizer management practices in particular. Okra [*Abelmoschus esculentus* (L.) Monech] commonly known as *bhindi*/lady's finger is grown through out the country as an important summer vegetable. It is well documented that the growth and yield of crop plants are greatly influenced by a wide range of nutrients. Adequate supply of nutrients is considered important for realizing the maximum yield in crops. Organic manure with chemical fertilizers and their method of application help in improving the fertility and productivity and physical condition of soil (Abusaleha and Shamugavelu, 1988) and low nitrogen loss due to slow release of nutrients from organic manures is an additional advantage. Presently, vermicompost is widely used for cultivation of vegetables, fruits, flowers, spices and medicinal plants. It is a rich mixture of major and minor plant nutrients. On an average, vermicompost contains 1.87 percent nitrogen, 1.26 percent phosphorus and 1.20 percent potassium (Reddy and Reddi, 2002).

Vegetable and vegetable based cropping system show that vegetable crops respond well to nutrient supply through organic manures and chemical fertilizers (Kala *et al.,* 1991). Okra-radish crop rotation can be beneficial for vegetable growers under arid irrigated conditions of Bikaner. Radish grown on residual effect of applied vermicompost and fertilizers to okra can add more benefit to the marginal vegetable growers. Radish is a herbaceous crop belong to the family cruiciferae. It is a root-cum leafy vegetable suitable for tropical and temperate climate. Its plant is green and leafy with long white edible root. Thereafter, the present investigation was undertaken to find out the effect of integrated nutrient management on yield attributes and yield of okra [*Abelmoschus esculentus* (L.) Moench] and its residual effect on radish (*Raphanus sativus* L.) in arid region of Rajasthan.

MATERIALS AND METHODS

The experiment was conducted at College of Agriculture, Bikaner during *Kharif* season 2004 and residual radish crop during winter season of 2004-05. The soil was loamy sand and low in organic matter. The soil pH was 8.4. It was low in organic carbon (0.09 %), available nitrogen (64.40 kg ha^{-1}) and available phosphorus (9.80 kg ha^{-1}) and medium in potassium (151.34 kg ha^{-1}). The treatments comprised four levels of vermicompost (0, 3, 6 and 9 tonnes per hectare) and four combinations of fertilizers (0, 30:15:15 kg NPK ha^{-1} , 60:30:30 kg NPK ha^{-1} and 90:45:45 kg NPK ha^{-1} were laid out in randomized block design with three replications. Nitrogen as per treatments was applied through urea in two split doses i.e. one at the time of sowing and another at 30 days after sowing the main crop. Phosphorus, potassium and vermicompost were applied at the time of sowing the main crop. Okra variety VRO 6 (proposed name - Kashi Pragati) was sown at 30 x 30 cm spacing using 10 kg seed ha^{-1} on 18.08.2004. In rabi season, in the same field, radish variety Japanese white was grown on 04.12.2004 as the residual crop following same layout plan as that for okra. The data of yield attributes and yield was observed of main crop at first picking and residual crop at harvest.

RESULTS AND DISCUSSION

Effect of vermicompost

Application of increasing levels of vermicompost at 6 t ha^{-1} enhanced the length of fruits, width of fruits, fresh weight of fruit, dry weight of fruit at first picking, number of picking and yield of okra. The effect of different levels of vermicompost from 0 to 6 t ha^{-1} was significant to each other; however, the effect of 9 t ha^{-1} was found to be at par with 6 t vermicompost ha^{-1} (Table 1). The magnitude of increase under 6 t vermicompost ha^{-1} were 38.49 and 10.28 per cent in length of fruits, 37.89 and 11.97 per cent in width of fruits, 37.88 and 9.64 per cent in fresh weight of fruit, 37.84 and 10.87 per cent in dry weight of fruit at first picking, 16.67 and 6.33 per cent in number of picking and 37.59 and 9.86 per cent in yield of okra over control and 3 t vermicompost ha^{-1}, respectively. However, the increment in days taken to flower initiation, days taken to fruit initiation, days taken to first fruit picking and moisture content in fruits at first picking was found statistically non significant due to application of vermicompost in okra crop. Further, root length, root width, root weight and root yield of residual crop radish also increase significantly with increasing levels of vermicompost up to 6 t ha^{-1} in main crop (Table 2). The significant increase due to application of vermicompost at 6 t ha^{-1} was 15.90 and 5.92 per cent root length, 13.54 and 3.96 per cent root width, 42.02 and 13.94 per cent root weight and 29.05 and 10.24 per cent root yield of residual crop radish as compared to control and vermicompost at 3 t ha^{-1}, respectively. It might be due to beneficial effect of vermicompost in supplying plant nutrients and increasing greater partitioning of metabolites towards sink (fruits) and adequate transformation of nutrients in accumulating dry matter in plants. The significant improvement in yield and yield attributes with addition of vermicompost seems to be on account of greater accumulation of dry matter resulting increased fruit size and weight because it produce the favourable macro and micro-nutrients to the metabolic activities of plants. Indirectly, it increased the photosynthetic activities of plants as revealed by increase in chlorophyll content by application of vermicompost which improved the yield of okra. These findings are in agreement to those reported by with Senthil Kumar and Sekar (1998)

Table 1. Effect of organic and inorganic sources of nutrients on yield attributes and yield of okra

Treatments	Days taken to flower initiation	Days taken to fruit initiation	Days taken to first fruit picking	Length of fruits at 1^{st} picking (cm)	Width of fruits at 1^{st} picking (cm)	Fresh weight of fruit at 1^{st} picking (g)	Dry weight at 1^{st} picking (g/fruit)	Moisture content in fruits at 1^{st} picking (g/100 g)	Number of picking	Yield (q ha^{-1})
Vermicompost (t ha^{-1})										
Control	38.70	42.77	46.28	6.59	0.95	6.6	0.74	88.63	7.2	68.26
3 t ha^{-1}	39.28	43.30	46.43	8.27	1.17	8.3	0.92	88.73	7.9	85.49
6 t ha^{-1}	39.43	43.43	46.79	9.12	1.31	9.1	1.02	88.77	8.4	93.92
9 t ha^{-1}	39.92	43.92	46.92	9.44	1.35	9.4	1.07	88.78	8.6	97.50
SEm±	0.366	0.370	0.366	0.187	0.024	0.187	0.021	0.061	0.192	1.934
CD at 5 %	NS	NS	NS	0.540	0.069	0.540	0.060	NS	0.555	5.587
Fertilizers (kg ha^{-1})										
F_0	39.42	43.45	46.95	6.82	0.97	6.8	0.76	88.67	6.9	70.50
F_1	39.55	43.55	47.05	7.81	1.13	7.8	0.89	88.70	7.8	80.56
F_2	39.68	43.70	47.20	9.19	1.30	9.2	1.02	88.74	8.6	94.87
F_3	38.68	42.72	46.21	9.61	1.36	9.6	1.07	88.80	8.8	99.24
SEm±	0.366	0.370	0.366	0.187	0.024	0.187	0.021	0.061	0.192	1.934
CD at 5 %	NS	NS	NS	0.540	0.069	0.540	0.060	NS	0.555	5.587

in okra, Kalambasa and Deska (1998) in radish and sweet pepper, Buckerfield *et al.* (1999) in radish.

Effect of fertilizers

Further an application of fertilizer combinations up to 60:30:30 kg NPK ha^{-1} significantly enhanced the length of fruits, width of fruits, fresh weight of fruit, dry weight of fruit at first picking, number of picking and yield of okra. The effect of different levels of fertilizer combinations up to 60:30:30 kg NPK ha^{-1} was significant to each other; however, the effect of 90:45:45 kg NPK ha^{-1} was found to be at par with 60:30:30 kg NPK ha^{-1} (Table 1). The magnitude of increase under 60:30:30 kg NPK ha^{-1} were 34.75 and 17.67 per cent length of fruits, 34.02 and 15.04 per cent in width of fruits, 35.29 and 17.95 per cent in fresh weight of fruit, 34.21 and 14.61 per cent in dry weight of fruit at first picking, 24.64 and 10.26 per cent in number of picking and 34.57 and 17.76 per cent in yield of okra over control and 30:15:15 kg NPK ha^{-1}, respectively. However, the increment in days taken to flower initiation, days taken to fruit initiation, days taken to first fruit picking and moisture content in fruits at first picking was found statistically non significant due to application of fertilizer in okra crop. Further, root length, root width, root weight and root yield of residual crop radish also increased significantly with increasing levels of fertilizer combinations up to 30:15:15 kg NPK ha^{-1} in main crop (Table 2). The significant increase due to application of fertilizer combinations up to 30:15:15 kg NPK ha^{-1} was 10.66 per cent root length,10.42 per cent root width, 32.38 per cent root weight and 22.70 per cent root yield of residual crop radish as compared to control. The beneficial effects of fertilizers on these parameters might be due to its contribution in supplying additional plant nutrients. It could be efficient and greater partitioning of metabolities and adequate transformation of accumulated dry matter which led to increased length and width and weight of fruits. An improvement in yield and yield components due to fertilizers could be attributed to overall improvement in plant growth as resulted by increased plant height, number of pickings, size and weight of fruits and dry matter content in fruits, which might be due

Table 2. Residual effect of organic and inorganic sources of nutrients on length, width, weight and yield of root of radish at harvest

Treatments	Root length (cm)	Root width (cm)	Root weight (g per root)	Root yield (q ha^{-1})
Vermicompost (t ha^{-1})				
Control	17.30	3.47	111.76	161.86
3 t ha^{-1}	18.93	3.79	139.30	189.47
6 t ha^{-1}	20.05	3.94	158.72	208.88
9 t ha^{-1}	20.14	4.03	162.01	212.35
SEm±	0.380	0.077	5.357	5.539
CD at 5 %	1.098	0.222	15.471	15.997
Fertilizers (kg ha^{-1})				
F_0	17.82	3.55	116.57	166.51
F_1	19.05	3.80	139.94	189.93
F_2	19.72	3.92	154.31	204.31
F_3	19.84	3.96	160.97	211.81
SEm±	0.380	0.077	5.357	5.539
CD at 5 %	1.098	0.222	15.471	15.997

to increased supply of fertilizers and other plant nutrients. These results are in agreement with the findings of Abdul and Aarf (1986), Rao and Subramaniam (1991), Farag and Damrany (1994) and Chattopadhyay and Sahana (2000) in okra.

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Charactrization of some electrochemical and chemical properties of waterlogged soils of surah lake of Ballia district

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Proper knowledge of soil resource with respect to characteristics, use potential and limitations is extremely important for optimizing land use and productivity potential. A sizeable low lying area in our country constitute *DIARA LANDS* which are put under floating rice (FR) cultivation. Flooding or submergence of a soil brings about several chemical and electrochemical changes thereby, influencing the growth and yield of rice plants largely by controlling the availability of plant nutrients and regulating their uptake by rice roots (Shioiri and Tanada, 1954; Ponnamperuma, 1955). Flooding also alters the character of the microbial flora in soils. The biochemical and microbial changes may mark soil differences to some extent and also influence the growth of plants in flooded soils. The major biochemical functions in flooded soils are solubilization, mineralization, oxidation and reduction. Detailed studies on the physical and chemical properties of flooded water were started in 1981 in Bangladesh by Whitton and his co-workers (Whitton and Rother, 1988 a,b; Whitton *et al.*, 1988 a and b). Similar studies commenced in Thailand in 1983 (Setter *et al*, 1988 and Whitton and Catling 1986.) Submerged soils possess a typical physico- chemical and microbial environment being unique in their nutrient and production potential. Characterization of such peculiar soil's eco-system becomes imperative to have knowledge of about physico- chemical and electrochemical environment of these soils for sound land management and production. There is an ox-bow lake in Ballia district popularly known as *SURAHA LAKE*. It covers an area of 2602.18 hectares of perennial water. During monsoon it inundates low- lying area thus extending the total area of water to about 3642.25 hectares. The low- lying land of the lake is subjected to flood each year in rainy season when ever river Ganges and its tributaries are in spate. The sudden rise in water level is the main feature of this region. In this very unique ecosystem a peculiar traditional variety- *Jaisuria* (floating rice) is grown successfully. Since continuous flooding causes a series of physicochemical, biochemical and microbiological changes in the soil.

The present investigation was conducted in arable land of Suraha lake of Ballia district during the *Kharif* seasons of 2004 and 2005. Through a visual reconnaissance survey of the lake, the arable land was divided into two groups *viz;* lowland and semi lowland depending on the water logging.

Lowland remains permanently under waterlogged condition while semi-lowland is temporarily (about 8-9 months) waterlogged. This area remains muddy or dried, in the months of May and June before the onset of monsoon rain. Five villages around the low-lying area of Suraha Lake i.e. Basantpur(LS_1), Surajpura(LS_2), Maritar(LS_3), Phulwaria(LS_4) and Salempur(LS_5) were selected as landing stations for the purpose of study. For the convenience of study, at each landing station two spots (10 m x 10 m) out of which one indicating floating rice spot-l (A_1E_1) and another floating rice spot-2 (A_2E_2) (well marked by fixing bamboo sticks) were fixed at the sites of soil sample collection. The distance between these two spots was about 100 meters apart towards the lake. Thus, the sample collection was confined to these two spots only. From experimental spots muddy soil samples were collected from the upper soil surface to a depth of 12 cm at different sampling stages (i) before sowing (ii) after flooding and (iii) at the time of tillering, milking, and maturity and after harvesting. The soil samples were analyzed for mechanical composition (sand, silt and clay), chemical properties (pH, EC, CEC, $CaCO_3$ and OC) and some electrochemical properties such as Eh, specific conductance and iron content. Standard methods and procedures as described by Chopra and Kanwar (1986), Piper (1968) and Jackson (1973) were followed for the analysis of soil.

RESULTS AND DISCUSSION

General Characteristics of soil

Physico-chemical properties of study sites are presented in Table 1. Overall the particle size analysis data revealed that soils of study area were fine textured in nature which is typical characteristic of lake soils. Soil reaction was saline and the pH of soils ranged from 7.6 to 8.2. The EC value ranged from 0.22 to 0.96 d Sm^{-1} irrespective of sampling sites, but soluble salt content of soil was within the normal range. Since the cation exchange capacity (CEC) of soil is governed by the kind and amount of clay therefore, the particle size proportion showed direct bearing on CEC of soil and accordingly the CEC was higher (22.75-32.50 cmol p+ kg^{-1}) in clayey soils and lower in clay loam, loam and silt loam (16.39-18.27 cmol p+ kg^{-1}). Data pertaining to organic carbon status of study area revealed that these soils were medium to high in organic carbon. Free $CaCO_3$ content of study area soils ranged from 2.17 to 8.40 per and C_1 (LS_3) and E_2 (LS5) sites were calcareous in nature.

Electrochemical Properties

Water logging/ flooding of soil has marked influence on soil properties and availability of plant nutrients. Among the important electrochemical properties, changes that affect fertility are decrease in redox potential (Eh), change in both soil and flood water pH and change in electrolytic conductivity (EC) and change in Fe and Mn concentrations (Ponnamperuma 1985). The present investigation is confined to study the changes in Eh, pH, specific conductance and Fe activity in water logged soils of *SURAHA LAKE*.

Redox Potential

The most distinct physico-chemical change brought about by flooding is the periodical change in oxidation- reduction regime of soil. In present investigation the whole study area was clearly demarked in to five landing stations (such as: LS_1, LS_2, LS_3, LS_4 and LS_5). From all these spots soil samples were collected periodically as before flooding (or 0 days after flooding), 20 DAF, 40 DAF, 60 DAF and 80 DAF. The data pertaining

Table 1. General Characteristics of Suraha Lake soils (before submergence)

Landing Stations	Floating Rice Spots	Sand (%)	Silt (%)	Clay (%)	Textural class	pH	EC (dSm^{-1})	CEC [cmol (p+) kg^{-1}]	CaCO3 (%)	OC (gkg^{-1})
LS1	A1	5.56	32.47	61.97	Clay	7.7	0.29	22.75	2.60	6.7
	A2	6.55	25.43	68.02	Clay	7.8	0.24	23.20	2.17	9.0
LS2	B1	30.60	28.80	40.60	Clay loam	7.8	0.35	18.27	4.57	8.3
	B2	30.15	26.35	43.50	Clay loam	7.6	0.22	18.00	3.87	6.5
LS3	C1	26.30	25.19	48.50	Clay	7.7	0.31	32.50	6.50	9.2
	C2	20.60	30.80	48.60	Clay	7.7	0.31	28.20	4.00	9.1
LS4	D1	10.70	48.90	40.40	Silt clay	7.7	0.51	17.10	3.45	7.8
	D2	15.40	60.90	23.70	Silt loam	7.9	0.45	17.10	3.20	8.1
LS5	E1	26.00	48.50	25.50	Clay loam	8.0	0.96	16.39	6.30	9.1
	E2	31.50	49.40	19.10	Loam	8.2	0.58	16.62	8.40	8.1

to oxidation reduction status (Eh) of soil is given in table 2. Redox potential (Eh) of well aerated soil ranged from + 561 to +589 mV, being lowest at E_1 (LS_5) and highest at A_1 (LS_5). Aerated soils have characteristics redox potential in the range of +400 to +700 mV (Patrick and Reddy 1978) and the water logged soils exhibit Eh as low as -250 to -300 mV. All landing stations followed the same pattern wherein Eh decreased sharply within first 20 DAF and then decreased gradually to a minimum value at their respective site of landing station i.e. -123 and -117 mV at LS_1, -139 and -125 mV at LS_2, -139 and -132 mV at LS3, -127 and -132 mV at LS_4 and -130 and -134 mV at LS_5 during next 20 to 40 DAF. Several studies have shown that redox potential (Eh) is very closely linked to oxygen (O_2) status of soils and dramatic reduction in Eh of water logged soils in first few days is caused irrespective of their pH, organic matter and easily reducible Fe and Mn contents. The magnitude of depression is more pronounced during the stage of water logging (Yadvinder Singh *et al.* 1992). Katyal (1977) also reported more reduction in non-calcareous soils than calcareous and sodic soils. The fall in redox potential has direct bearing on the amount of easily reducible Fe and Mn oxides, NO_3^- and SO_4^{--} on one hand and amount of organic matter on the other hand. Redox potential after reaching at its maximum started increasing asymptotically with the advance of submergence at all landing stations of the study area. The subsequent increase in Eh is associated with the increasing oxygen content in soil and stagnating water and the course is determined by the nature and extent of oxidized component and kind and content of organic matter of soil. Suraha lake soils showed a wide variation (+589 to -139 mV), but further decrease in Eh might have been prevented by virtue of highly reducible iron (Fe) present in soil system. This chemical behavior is helpful in preventing the production of toxic reduced substances in submerged rice soils.

pH

The data showed that before flooding the pH of soils varied from 7.6 to 8.2 being minimum at B_2 (LS_2) and maximum at E_2 (LS_5). After submergence the pH decreased as the period of submergence proceeded (Table 2). Soil reaction during submergence showed marked behavior. During 20 DAF to 40 DAF period the pH at A_1, B_1, B_2 and C_1 sites further lowered, whereas at C_2, D_1, D_2 and E_2 sites pH remained unchanged and next 40 DAF to 60 DAF, pH further decreased and then remained constant. Similarly, at A_1 site during 40 DAF to 80 DAF the pH remained unchanged. The decrease in pH of soils following submergence may be ascribed by several electro-chemical and bio chemical changes. Microbial decomposition of organic matter produces CO_2 which forms carbonic acid and decreases pH of alkali and calcareous soils upon submergence (Ponnamperuma 1972). The increase in pH on soil submergence probably was caused by the reduction of Fe (Ponnamperuma *et al.* 1966). The redox reactions in soils involve the transfer of electrons and H^+ which directly influence H^+ concentrations. A low redox potential generally results in higher pH (Thord, 1979). Organic matter can also influence pH changes by intensifying reduction, and through the concentration of CO_2 and organic acids. All soils attained a stable pH after 2-4 weeks of submergence. The present study shows the stability in pH changes after 40 DAS. The pH of neutral and slightly alkaline soils is regulated by the $CaCO_3$ - CO_2-H_2O equilibrium (Ponnamperuma, 1964). The stabilization of the pH values of soils at 7.0 to 7.6 after 3-4 weeks after flooding (Table 2) has an important role in the nutrition of rice plants. The present study shows that the pH range of all soils at all experimental plots is favorable for the normal growth of *Jaisuria* rice.

Specific Conductance

Electric conductivity measured in one cubic centimeter soil at 25°C is called specific conductance of soil and it measures the kind and total concentration of ions in soil solution. Specific conductivity may be treated as a diagnostic tool for the study of the concentration of ionic reduction products present in soil. Thereby, changes in specific conductance of a flooded soil throw a considerable light on chemical changes occurring therein after submergence. Specific conductance of soils of all spots showed a slight increase up to tillering, thereafter, a gradual decrease was noted from

40 DAS to 80 DAS (Table 2). Reduction of ferric ion into ferrous, organic matter mineralization, changes of soils pH towards neutrality to salinity (i.e. 7.1 to 8.2 pH values) and presence of bicarbonate and soluble hydroxides might be reasonable causes for observing a peak of specific conductance at tillering stage after submergence of Suraha lake soils by the end of June. Specific conductance increased after submergence at a slower rate, attained maximum values and then declined to fairly stable values during their course of time. Ponnamperuma (1978) also noted that increase in conductance during first few weeks of submergence is due to mobilization of Fe^+ and Mn^+, accumulation of NH_4^+, HCO_3^- and $RCOO^-$ and displacement of cations from soil colloids by Fe^{+2}, Mn^{+2} and NH_4^+.

Iron content

The chemistry of flooded soils has been dominated more by iron than by any other redox-element (Patrick and Reddy, 1978). The most dramatic change that occurs when a soil is submerged and its Eh falls is the reduction of Fe^{+3} to Fe^{+2} consequently soil colour also change from brown to gray. The main reason for this dominance was the presence of more amount of iron that could undergo reduction. The Fe^{++} concentration along with submergence showed a gradual increase up to flowering i.e.140 DAS (Table 2). An instant increase in iron content was observed just after submergence. The range of

Table 2. Changes in electrochemical and chemical properties of water logged soils of Suraha Lake

Landing Station	LS_1		LS_2		LS_3		LS_4		LS_5	
	A_1	A_2	B_1	B_2	C_1	C_2	D_1	D_2	E_1	E_2
Before flooding										
pH	7.7	7.8	7.8	7.6	7.7	7.7	7.7	7.9	8.0	8.2
Eh	589	581	574	569	567	575	579	572	561	567
Specific conductivity	150	100	130	75	60	40	50	70	80	90
Fe++	4.5	5.0	4.6	6.2	5.2	5.7	6.2	6.2	7.2	6.5
20 DAF										
pH	7.6	7.1	7.7	7.5	7.4	7.3	7.3	7.8	7.8	8.1
Eh	-87	-99	-119	-111	-116	-118	-112	-117	-115	-118
Specific conductivity	300	150	250	100	250	150	110	110	150	230
Fe++	16.5	12.10	9.20	12.30	12.70	11.30	11.50	11.80	12.30	12.95
40 DAF										
pH	7.5	7.20	7.6	7.4	7.2	7.3	7.3	7.8	7.9	8.1
Eh	-123	-117	-139	-125	-139	-132	-127	-132	-130	-134
Specific conductivity	300	140	230	170	320	340	750	900	850	600
Fe++	17.90	13.80	11.40	13.60	13.00	12.50	12.70	12.00	13.40	14.40
60 DAF										
pH	7.5	7.00	7.5	7.3	7.20	7.2	7.2	7.50	7.50	7.60
Eh	-119	-114	-117	-111	-123	-118	-114	-116	-117	-119
Specific conductivity	230	110	190	130	270	290	350	350	350	350
Fe++	18.40	14.10	11.80	13.90	13.10	13.50	13.80	12.10	13.80	14.90
80 DAF										
pH	7.5	7.00	7.5	7.1	7.2	7.2	7.2	7.30	7.20	7.30
Eh	-117	-112	-115	-108	-120	-115	-110	-113	-114	-117
Specific conductivity	180	600	1300	900	210	230	250	300	250	250
Fe++	18.50	13.60	10.30	12.70	13.20	12.80	12.90	12.00	12.70	13.20

Available Fe++ = ppm; Specific conductivity = Micro mhos/cm; Eh = in millivolts; DAF = days after flooding iron before flooding was in between 4.5 ppm to 7.2 ppm at various landing stations. Maximum increase in Fe^{++} content was observed during 20 DAF to 40 DAF and then Fe^{++} content increased very slowly during 40 DAF to 60 DAF at all landing stations, but afterwards barring A_1 (LS_1) and C_1 (LS_3) sites re-precipitation of (Fe^{++}) iron might have occurred whereby soluble (Fe^{++}) iron content showed decreasing trend during 60 to 80 DAF (Table 2). The concentration of water soluble Fe^{++} at submergence increases quickly and may rise upto 600 ppm with in 1-2 weeks after flooding and then declines to a fairly stable values. The redox potential regulates the solubility and amount of Fe^{++} (Ponnamperuma, 1978 and Sahrawat, 2009). The data showed that presence of high amount of iron might have played a dominant role in soil reduction and regulating the availability of nutrients to plants. The maximum Fe^{++} concentration was observed at six weeks after flooding with a gradual increase in its concentration. Reduction of ferric iron is very important in providing adequate Fe^{++} for the nutritional requirement of the rice plant. Reduction of Fe^{+++} to Fe^{++} not only eliminates iron deficiency in soil but also depress manganese toxicity in acid soils and aluminum toxicity in submerged acid sulphate soils (Tanado and Yashida, 1978; IRRI, 1967; Tanaka and Yoshida, 1970). The findings of present study have made a better understanding of electrochemical and chemical changes occurred during the period of submergence.

The whole series of changes during the course of study may be summarized that soils showed a drastic fall in redox-potential at all landing stations after submergence. Thereafter, a gradual increase of redox-potential (Eh) was noted which remained constant. At pre sowing stage, pH ranged from 7.7 to 8.2, but all soils attained a fairly stable pH after 2-4 weeks of submergence. The specific conductance of soil of all spots showed a slight increase up to tillering, there after; a gradual decrease was noticed from 40 DAS to 80 DAS. The magnitude of Fe^{++} concentration along with submergence showed a gradual increase up to flowering i.e. 140 DAS. The range of iron before flooding was in between 4.5 -7.5 ppm at various landing stations. Due to prolonged flooding the redox-potential increased rapidly, there after a decreasing trend was noticed. Suraha Lake is a unique agro-ecological area favourable for sustainable production of floating rice on account of its matchless innate character which can be exploited properly for FR cultivation.

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Performance of chickpea variety CNG - 663 in front line demonstration under irrigated conditions

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ABSTRACT

Total 130 Front line demonstrations on Chickpea variety GNG-663 were conducted at farmers' fields in district Jhunjhunu (Rajasthan) during *rabi* 2005-06, 2006-07, 2007-08 and 2009-10. On an average, 17.5% higher grain yield was recorded under demonstrations than the farmer's traditional practices. The extension gap, technology gap and technology index were 197.8 kg/ha, 876 kg/ha and 38.9%, respectively. An additional investments of Rs.1499/ha coupled with scientific monitoring of demonstrations and non-monetary factors resulted in additional return of Rs. 3141/ha. Fluctuating minimum support price of chickpea during different years influenced the economic returns per unit area. On four years average basis incremental benefit: cost ratio was found as 2.1.

Key words : Chickpea, demonstration, gap analysis, economics, grain yields

Chickpea commonly known as gram is an important rabi pulse crop of India. It occupies about 38.7% of area and 48.3% of the total pulses production in India. In Rajasthan state the total area under chickpea cultivation is 12.31 lakh ha (16.7% of the nation) with a production of 5.73 lakh tonnes (9.7% of the nation). Average productivity of chickpea is very low in the state (465 kg/ha). The major causes of low productivity of chickpea in Rajasthan includes several biotic and abiotic stresses besides unavailability of quality seeds of improved varieties in time and non-adoption of recommended production and plant protection technologies. Therefore, it is important to demonstrate the high yielding chickpea varieties and their production technologies to boost chickpea production. Recognizing the importance of pulses in Indian Agriculture and urgent need to ensure household nutritional security, the Ministry of Agriculture, Govt. of India has taken the innovative methodology to boost up the production of pulse crops. A wide gap exists between the available techniques and its actual application by the farmers which is reflected through poor yield in the farmers' fields. There is a tremendous opportunity for increasing the production and productivity of chickpea crop by adopting the improved technologies. A range of chickpea production technologies have been generated at agricultural universities and research stations, but the productivity of chickpea is still very low due to poor transfer of technologies from the research farms to the farmers' fields. Only a little new knowledge percolates to the farmers' fields, hence a vast gap has been observed between knowledge production and knowledge utilization.

To achieve the target of pulse production for the period of 2007-2012(32 m.t.), it is necessary to concentrate efforts on scientific cultivation of chickpea, the most important pulse crop of India. Front Line Demonstration (FLD) on chickpea including recently released, early maturing, high yielding, bold seeded, disease resistant varieties with IPNM, IWM & IPM on farmers' field may be helpful. Hence, the FLDs on chickpea were conducted under irrigated conditions in Jhunjhunu district of Rajasthan during rabi, 2005-06 to 2009-10 to:

1. Study the performance of recognised & recommended high yielding chickpea variety with recommended package of practices.

2. Collect and analyse feedback information for further improvement in research and extension programme.

MATERIALS AND METHODS

Front line demonstrations on chickpea variety "GNG-663" were conducted at farmers' field in district Jhunjhunu (Rajasthan) during rabi 2005-06, 2006-07, 2007-08 and 2009-10. The soils of the district is generally sandy loam in texture, low in N, low - medium in P and medium to high in K. All the demonstrations were of one acre area each and were conducted using recommended package of practices. Farmers were provided with quality seed of Chickpea variety "GNG-663" during all the years of the study. The sowing was done during mid-October to last week of October under assured irrigated conditions. Crop was harvested during last week of March. The demonstrations on farmers' fields were regularly monitored by the scientists of Krishi Vigyan Kendra, Jhunjhunu from sowing to harvesting. The grain yield of demonstration crop was recorded and analysed. Different parameters as suggested by Yadav *et al.* (2004) were used for calculating gap analysis, costs and returns. The detail of different parameters is as follows:

1. Extension gap = Demonstration yield (D_1) - Farmer's practice yield (F_1)
2. Technology gap = Potential yield (P_1) - Demonstration yield (D_1)
3. Technology index = Potential yield (P_1)- Demonstration yield (D_1) x 100/ Potential yield (P_1)
4. Additional return = Demonstration return (D_r)- Farmer's practice return (F_r)
5. Effective gain = Additional return (A_r) - Additional cost (A_c)
6. Incremental B:C ratio = Additional return (A_r) / Additional cost (A_c)

RESULTS AND DISCUSSION

Grain yield

The increase in grain yield under demonstration was 11.8 to 26.6% over farmers' local practices. On an average, 17.5% yield advantage was recorded under demonstrations carried out with improved cultivation technology as compared to farmers' traditional way of chickpea cultivation.

Gap analysis

An extension gap of 143-269 kg/ha in yield was found between demonstrated technology and farmers' practices during different years. Average extension gap was 197.8 kg/ha (Table 1). The extension gap was the lowest (143 kg/ha) during 2005-06 and was the highest (269 kg/ha) during 2009-10. Such gap might be attributed to adoption of improved technology in demonstrations which resulted in higher grain yield than the traditional farmers' practices. Wide technology gaps were observed during different years, the lowest (519 kg/ha) being during 2006-07 and the highest (1028 kg/ha) during 2005-06. On four years average basis, the technology gap of total 130 demonstrations was found as 876 kg/ha. The difference in technology gap during

Table 1. Grain yield and gap analysis of front line demonstrations on chickpea at farmers' field

Year	No. of demonstrations	Variety	Potential yield (Kg/ha)	Demonstration yield (Kg/ha)	farmers' practice yield (Kg/ha)	Increase over farmers practice (%)	Extension gap (Kg/ha)	Technology gap (Kg/ha)	Technology index (%)
2005-06	10	GNG-663	2250	1222	1079	13.25	143	1028	45.7
2006-07	40	GNG-663	2250	1731	1548	11.84	183	519	23.1
2007-08	40	GNG-663	2250	1263	1067	18.36	196	987	43.9
2009-10	40	GNG-663	2250	1280	1011	26.60	269	970	43.1
Overall average	32.5	-	2250	1374	1176.3	17.5	197.8	876	38.9

Table 2. Economic analysis of front line demonstrations on chickpea at farmers' field

Year	Cost of cash input (Rs./ha)		Additional cost in demonstration (Rs./ha)	Sale price (MSP) of grain (Rs./qtl.)	Total returns (Rs./ha)		Addition return in demonstration (Rs./ha)	Effective gain (Rs./ha)	Incremental B:C ratio (IBCR)
	Demonstration	farmers' practice			Demonstration	farmers' practice			
2005-06	3145	2108	1037	1425	17414	15376	2038	1001	2.0
2006-07	3144	1322	1822	1450	25100	22446	2654	832	1.5
2007-08	2800	1240	1560	1600	20208	17072	3136	1576	2.0
2009-10	3825	2250	1575	1760	22528	17794	4734	3159	3.0
Overall average	3228.5	1730	1498.5	1558.8	21312.5	18172	3140.5	1642	2.1

different years could be due to more feasibility of recommended technologies during different years. Similarly, the technology index for all the demonstrations during different years were in accordance with technology gap. Higher technology index reflected the inadequate proven technology for transferring to farmers and insufficient extension services for transfer of technology.

Economic analysis

Different variables like seed, fertilizers, biofertilizers and pesticides were considered as cash inputs for the demonstrations as well as farmers practice. On an average, an additional investment of Rs. 1499/ ha was made under demonstrations. Economic returns as a function of grain yield and minimum support price (MSP) sale price varied during different years. Maximum returns were obtained during the year 2006-07 and 2009-10 due to higher grain yield and higher MSP sale rates as declared by GOI, respectively. The higher additional returns and effective gain obtained under demonstrations could be due to improved technology, non-monetary factors, timely operations of crop cultivation and scientific monitoring. The lowest and highest incremental benefit: cost ratio (IBCR) were 1.5 and 3.0 in 2006-07 and 2009-10, respectively (Table 2). Overall average IBCR was found as 2.1.The results confirm the findings of front line demonstrations on oilseed and pulse crops by Singh *et al.* (2000), Singh *et al.* (2002), Yadav *et al* (2004) and Lathwal, O.P.(2010).

CONCLUSION

Adoption of improved chickpea production technologies in demonstrations, on an average increased the 17.5% grain yield over the local check. Such increase was recorded with little extra spending of Rs. 1499/ha. This amount is so less that even a small and marginal farmer can afford. This proved that it is not the cost that deters the farmers from adoption of latest technology but ignorance is the primary reason and it is quite appropriate to call such yield gap as extension gap. The extension gap was found to be 197.8 kg/ha. The IBCR (2.1) is sufficiently high to motivate the farmers for adoption of technology. Therefore, front line demonstration program was effective in changing attitude, skill and knowledge of farmers towards improved / recommended practices of chickpea cultivation including adoption. This also improved the relationship between farmers and scientists, and built confidence between them. The demonstration farmers acted also as primary source of information on the improved practices of chickpea cultivation and also acted as source of good quality pure seeds in their locality and surrounding area for the next crop. The concept of front line demonstration may be applied to all farmer categories including progressive farmers for speedy and wider dissemination of the recommended practices to other members of the farming community. This will help in the removal of the cross-sectional barrier of the farming population.

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Response to inoculation of nitrogen-fixing and phosphate-solubilising micro-organisms on growth and yield of basmati rice (*Oryza sativa* L.)

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ABSTRACT

A field experiment was conducted during *kharif* season of 2009 at the research farm of IARI, New Delhi to study the influence of N_2-fixing and P-solubilising micro-organisms as a component of integrated nutrient management for nutrition of rice crop. In the experiment, 12 treatments including microbial inoculants like Blue Green Algae (BGA), *Azolla, Azotobacter*, Phosphate Solubilizing Bacteria (PSB) and AM fungi were inoculated alone or in combination along with a common fertilizer dose of $N_{90}K_{60}$ and these were compared with recommended dose (N_{120}+ P_{60}+ K_{60}) of fertilizers. Microbial-inoculants were applied as per their recommendation to rice crop. It was found that plant growth, yield attributes and yields were significantly influenced due to the combined inoculation of BGA and Azolla with PSB and AM fungi with 90 kg N + 60 Kg K_2O ha^{-1} and these inoculants showed at par increment in plant growth, yield attributed and yield as given by $N_{120}P_{60}K_{60}$. Single inoculation of BGA or *Azolla* with 90 kg N ha-1 also increased plant growth; yields attributes and yield as compared to the single inoculation with *Azotobacter*. Plant growth, yield attributes and yield obtained with *Azotobacter* was significantly inferior as compared with other bio-inoculants. Response of single application of PSB and AM fungi was comparable to BGA and *Azolla* application.

Key words : Basmati rice, economics, nitrogen-fixing micro-organisms, phosphate- solubilising micro-organisms, plant growth

Intensive cropping system like rice-wheat is under tremendous pressure due to ever increasing demand for food although there are signs of fatigue and decline in yield, especially in Indo-Gangatic plains where the level of grain production is 10 t ha^{-1}year-1 or more. Besides, a decline in factor productivity of fertilizers asking for higher and higher amounts of plant nutrients to obtain the same yield has been reported. This is due to declining soil fertility, especially its content of organic matter, over-mining and losses of nutrients from soil varying from 600 to 700 kg ha^{-1} every year against the application of 400 kg NPK ha^{-1}. In order to get sustainable production from this system Integrated Plant Nutrient System is suggested and N_2-fixing bio-fertilizers like *Azolla*, Blue Green Algae (BGA), *Azotobacter* and phosphate solubilizing bio-fertilizer like Phosphate solubilizing Bacteria (PSB) and Arbuscular mycorrhizae (AM) fungi have proved useful as a bio-fertilizer in some rice-growing countries (Roger *et al.* 1987).

Azolla is used as bio-fertilizer for rice cultivation in different countries and it contribute about 30 kg N ha^{-1} (Singh and Singh, 1986). Blue-green algae (cyanobacteria) can develop impressive blooms in rice fields and estimates on biological N2-fixation by BGA in rice fields range from a few to 80 kg ha^{-1} of N per crop, with an average of 27 kg (Roger *et al.* 1987). *Azotobacter* can fix atmospheric nitrogen in cereal crops without any symbiosis. *Azotobacter* has been reported to fix 15-20 kg ha^{-1} N year-1 (Paul and Verma, 2005). AM fungi is reported to have an ability to allow plant access to nutrient sources which are generally unavailable to the host plants and thus plants may be able to use insoluble sources of P when inoculated with mycorrhizal fungi (Singh and Rana, 2005). PSB are present in the rice rhizosphere and in rice soils, yet few experiments indicate a potential for increasing rice yield by the inoculation with such organisms. Thus, a number of studies on different bio-fertilizers have been undertaken in different parts of the world but informations are mostly lacking on consolidated effects of these bio-fertilizers in north-western Indian conditions especially Indo-Gangetic belt where rice-wheat system is predominant. Considering these facts, a field experiment was undertaken to study the influence of inoculation of N_2-fixing and P-solubilizing micro-organisms on growth and yield of basmati rice.

MATERIALS AND METHODS

A field experiment was conducted during *kharif* season (2009-2010) at the research farm of Indian Agricultural Research Institute, New Delhi, situated at a latitude of 28°40' N and longitude of 77°12' E, altitude of 228.6 meters above the mean sea level (Arabian Sea). The soils of experimental field was sandy clay loam and having 234 kg ha-1 alkaline permanganate oxidizable N, 18.0 kg ha^{-1} available P, 286 kg ha-1 1 N ammonium acetate exchangeable K and 0.56% organic C and the pH of soil was 7.4.

In experiment, 12 treatments, viz. T_1: BGA; T_2: *Azolla*; T_3: Azotobacter; T_4: Phosphate Solubilizing Bacteria (PSB); T_5: AM fungi; T_6: BGA + PSB; T_7: *Azotobacter* + PSB; T_8: *Azolla* + PSB; T_9: BGA + AM fungi; T_{10}: *Azolla* + AM fungi; T_{11}: *Azotobacter* + AM fungi and T_{12}: N_{120}+ P_{60}+ K_{60} (Recommended dose) were used. The experiment was laid out in randomized block design with 3 replications. A common dose of 90 kg N and 60 kg K_2O ha-1 was applied in all treatments, except T_{12}.

Azolla microphylla @ 1.0 t ha^{-1} and multani mitti based BGA having composite culture of four species viz., *Anabaena sp., Nostoc sp., Tolypothrix sp.* and *Aulosira sp.* were applied @ 1.5 kg ha^{-1} as top dressing 2 days after transplanting and for proper growth of these bio-fertilizers standing water (3-5 cm) was maintained in rice crop. Both *Azolla* and BGA multiplied for about 25-30 days and later decomposed when good mat developed and rice crop canopy developed shading effect. Biomass of *Azolla* (on dry weight basis) contained 3.7% N, 0.75% P, 4.2% K, iron 755 mg/kg, zinc 85 mg/kg, manganese 174 mg/kg and copper 17 mg/kg while dry biomass of BGA contained 4.1% N, 0.88% P, 4.7% K, iron 695 mg/kg, zinc 74 mg/kg, manganese 165 mg/kg and copper 21 mg/kg. *Azotobacter* and PSB were applied @ 500 g ha^{-1} through seedling root dip for 30 minute at the time of transplanting. AM fungi were applied @10 kg ha^{-1} as basal application at the time of transplanting. Twenty-four days old seedling of rice variety 'Pusa Basmati 1121' were transplanted at 20 cm × 10 cm spacing keeping 2 seedlings $hill^{-1}$.

Observations on plant growth and yield were taken as per standard procedures. Gross and net returns were calculated based on the grain and straw yield and their prevailing market prices of Basmati rice during the respective crop season. The data obtained from the experiment were statistically analyzed using the *F*-test as per standard procedure and LSD values at P = 0.05 were used to determine the significance of difference between treatment means.

RESULTS AND DISCUSSION

Plant growth

Plant height of basmati rice at 30, 60 and 90 DAT was significantly influenced due to the inoculation of N_2-fixing and P-solubilising micro-organisms (Table 1). The plant height due to combined inoculation of BGA and AM fungi along with a common dose of $N_{90}K_{60}$ was the highest at all the stages of crop but it was statistically *at par* with recommended dose of chemical fertilizer ($N_{120}P_{60}K_{60}$), inoculation of *Azolla* + PSB, *Azolla* + AM fungi, BGA + AM fungi and BGA + PSB along with a common dose of $N_{90}K_{60}$. Plant height with inoculation with *Azotobacter* was the lowest at all the stages of crop and it was significantly lower as compared to single as well as combined inoculation of two inoculants and recommended dose of chemical fertilizer. Single inoculation of *Azolla*, BGA, PSB and AM fungi also showed increased plant height but it was lower as compared to combined inoculation of N_2-fixing and P-solubilising micro-organisms. Number of tillers of rice at 30, 60 and 90 DAT was significantly influenced due to the inoculation of N_2-fixing and P-solubilising

Table 1. Effect of different treatments on plant growth parameters of basmati rice

Treatment	Plant height (cm)			No. of tillers hill^{-1}			Dry matter accumulation (g hill^{-1})		
	30 DAT	60 DAT	90 DAT	30 DAT	60 DAT	90 DAT	30 DAT	60 DAT	90 DAT
BGA	81.0	134.9	143.3	8.1	11.8	15.8	6.0	12.4	32.9
Azolla	81.7	130.6	142.8	9.1	12.8	15.1	6.1	11.7	32.7
Azotobacter	77.0	129.9	141.1	7.8	9.5	12.2	5.2	9.9	30.8
PSB	79.3	131.6	140.5	8.6	12.7	15.6	5.0	11.6	32.3
AM fungi	80.0	132.8	143.0	9.7	12.3	14.4	5.9	13.2	32.7
BGA + PSB	86.2	136.5	146.8	10.9	16.3	17.3	6.2	10.8	33.4
Azotobacter+ PSB	84.1	133.1	143.1	11.7	11.6	14.4	5.6	12.5	31.8
Azolla + PSB	85.7	134.6	145.0	13.0	14.1	19.3	6.2	12.5	33.9
BGA+ AM fungi	87.2	136.9	147.1	13.0	16.5	18.5	7.4	12.6	35.5
Azolla+AMfungi 35.1	86.0	134.8	145.8	12.0	13.0	17.0	6.1		12.1
Azotobacter + AM fungi	80.1	130.5	144.7	10.6	12.3	15.6	6.0	13.2	34.3
N_{120}+ P_{60}+ K_{60}	85.7	136.5	146.5	13.5	16.6	17.9	7.0	12.8	35.5
LSD (P=0.05)	4.7	4.4	3.9	2.6	3.5	3.4	NS	NS	2.6

DAT = Days after transplanting

micro-organisms. The tillers hill^{-1} due to the application of recommended dose of chemical fertilizers were the highest at 30 DAT but they were statistical at par with the tiller no. obtained with the combined inoculation of *Azolla* + PSB, *Azolla* + AM fungi, BGA + AM fungi and BGA + PSB. Similar trend was observed at 60 and 90 DAT. Dry matter accumulation of rice at 30 and 60 DAT in different treatments were not significantly different though the difference was significant at 90 DAT. At 30 and 60 DAT, dry matter accumulation was higher at combined application of two inoculants and recommended dose of chemical fertilizer as compared to single application of inoculants. Lowest dry matter accumulation was recorded with single inoculation with *Azotobacter*. Dry matter accumulation with single inoculation of *Azolla*, BGA, PSB and AM fungi also showed increment but it was lower as compared to combined inoculation of N_2-fixing and P-solubilising micro-organisms and chemical fertilization at recommended dose. Through inoculation, additional N_2 fixed by BGA and *Azolla* and additional mobilized/ solubilized phosphorus by AM fungi and PSB were made available to plant and recycled into soil and increased availability of these nutrients into soil led to increased number of tillers, dry matter accumulation and plant height of rice and this increment was comparable to the increment through recommended dose of chemical fertilizers. Increase in growth attributes might be due to higher availability of biological N and P (Meena and Shivay, 2010).

Yield attributes

Inoculation of N_2-fixing and P-solubilizing micro-organisms significantly influenced the effective tillers m^{-2}, panicle length and no. of total grains panicle^{-1} (Table 2). However, no. of filled grains panicle^{-1} and test weight were not significantly influenced due to different treatments. Inoculation of BGA + AM fungi gave highest no. of effective tillers but these were not significantly different from combined application of *Azolla* + PSB, *Azolla* + AM fungi, BGA + AM fungi and BGA + PSB. Same trend was observed in the panicle length also. The highest total grains panicle^{-1} were recorded when BGA + AM fungi

Table 2. Effect of different treatments on yield attributes in basmati rice

Treatment	Effective tillers hill^{-1}	Panicle length (cm)	No. of filled grains panicle^{-1}	No. of unfilled grains panicle^{-1}	No. of total grains panicle^{-1}	Test weight (g)
BGA	10.9	24.8	76.0	17.2	93.1	24.7
Azolla	9.8	22.3	75.5	15.5	91.0	26.4
Azotobacter	7.9	21.8	73.9	16.8	85.7	24.0
PSB	10.2	22.1	74.5	14.2	88.7	25.7
AM fungi	10.9	24.2	75.6	17.2	92.8	24.0
BGA + PSB	11.8	27.4	77.4	18.3	95.7	25.7
Azotobacter + PSB	9.7	24.7	75.9	17.2	93.1	24.6
Azolla + PSB	11.7	27.4	76.5	18.1	94.6	25.3
BGA + AM fungi	12.3	28.2	77.6	19.2	96.8	25.0
Azolla + AM fungi	10.7	23.3	76.8	18.0	94.8	24.6
Azotobacter + AM fungi	10.2	21.4	76.3	17.2	96.7	24.7
N_{120}+ P_{60}+ K_{60}	12.3	27.8	77.6	19.1	6.0	25.0
LSD (P=0.05)	2.3	4.1	NS	4.0	3.8	NS

was inoculated, however these no. were statistically *at par* with the treatments having combined inoculation of *Azolla* + PSB, *Azolla* + AM fungi, BGA + AM fungi and BGA + PSB and application of $N_{120}P_{60}K_{60}$. Among the filled and unfilled grains panicle^{-1}, data were significant in filled grains panicle^{-1} only. On all the yield attributes, single inoculation of Azotobacter performed poorly as compared to the single inoculation of BGA, *Azolla*, PSB and AM fungi. Increased tillering in plants led to higher number of panicles per unit area of lowland rice (Fageria, 2001). The increase in number of tillers hill^{-1} due to proper supply of N and P was recorded in the present study is in accordance with the findings of Singh *et al.* (2004). Single as well as combined inoculation of *Azolla*, BGA, PSB and AM fungi produced significantly higher and total number of grains panicle^{-1} as compared to single inoculation of Azotobacter (Singh *et al.* 2004). The N and P fertilization increased test weight of rice due to additional supply of N and P which increased the N and P concentration in grain and when N content increase in grain, crude protein content in grains also increased proportionally (Naik and Das, 2007). The significant effect of bio-fertilizers may be due to the effect of different strains group such as N_2fixers, nutrient mobilizing micro-organisms, which help in availability of these nutrients in available forms in the composted materials, and increased the levels of extractable N, P and K (Shaheen et al. 2007).

Yield and economics

Grain and straw yield of basmati rice increased significantly with combined inoculation of *Azolla* + PSB, *Azolla* + AM fungi, BGA + AM fungi and BGA + PSB as compared to single inoculation of *Azotobacter* (Table 3). However, increased yield due to *Azolla* + PSB, *Azolla* + AM fungi, BGA + AM fungi and BGA + PSB along with $N_{90}P_{60}K_{60}$ was statistical *at par* with application of recommended dose of chemical fertilizer ($N_{120}P_{60}K_{60}$). Grain and straw yield with single inoculation with *Azolla*, BGA, PSB and AM fungi was higher as compared to the single inoculation of *Azotobacter.* Significant effect of grain and straw yield was seen in biological yield of the crop and same trend was observed as found in grain and straw yield. Harvest index was not significantly influenced by the treatments and it varied between 19 and 22. The increase in grain and straw yields due to inoculation of N_2-fixing and P-solubilising micro-organisms can be explained on the basis of their positive effect on yield attributes like effective tillers, panicle length and no. of grains panicle^{-1}.

Table 3. Effect of different treatments on grain and straw yield of basmati rice

Treatment	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Biological Yield (t ha^{-1})	Harvest index (%)
BGA	4.29	16.58	20.87	20.5
Azolla	4.13	16.06	20.19	20.4
Azotobacter	3.74	15.91	19.66	19.0
PSB	4.04	16.25	20.29	19.9
AM fungi	4.26	16.22	20.48	20.8
BGA + PSB	4.63	16.74	21.34	21.8
Azotobacter + PSB	4.31	16.54	20.85	20.7
Azolla + PSB	4.58	16.72	21.31	21.5
BGA + AM fungi	4.71	16.75	21.46	21.9
Azolla + AM fungi	4.59	16.87	21.50	21.4
Azotobacter + AM fungi	4.49	16.44	21.09	21.3
N_{120}+ P_{60}+ K_{60}	4.75	16.87	21.59	22.0
LSD (P= 0.05)	0.56	0.54	1.04	NS

Table 4. Effect of different treatments on economics of bio-inoculants and chemical fertilizers in basmati rice cultivation

Treatment	Gross return (ha^{-1})	Net return (ha^{-1})	Benefit :cost Ratio (ha^{-1})
BGA	59453	38771	1.87
Azolla	57337	36595	1.76
Azotobacter	53343	32676	1.58
PSB	56647	35980	1.74
AM fungi	58857	37715	1.78
BGA + PSB	63307	42560	2.05
Azotobacter + PSB	59643	38951	1.88
Azolla + PSB	62553	41786	2.01
BGA + AM fungi	63850	42668	2.01
Azolla + AM fungi	62807	41565	1.96
Azotobacter + AM fungi	61503	40336	1.91
N_{120}+ P_{60}+ K_{60}	64347	43390	2.07
LSD (P= 0.05)	2785	5295	0.26

The increase in yields might be attributed to slow release of applied N and P due to the inoculation of N_2-fixing and P-solubilising micro-organisms (Singh and Mandal, 1997), which might have led to increased photosynthetic activity for longer period and finally increased dry matter accumulation.

Combined inoculation of BGA with AM fungi/ PSB along with a common dose of $N_{90}K_{60}$ gave the highest net return and this return was at par with the return given by sole chemical fertilizer application (Table 4). Among the treatments having single inoculation of different bio-fertilizers, BGA gave the highest net return followed by AM fungi. Benefit: cost ratio due to inoculation of different bio-fertilizers was comparable to application of chemical fertilizers. Benefit cost ratio varied between 1.58 and 2.07 and the lowest ratio was recorded due to the inoculation of *Azotobacter*. Combined application of N_2-fixing and P-solubilising micro-organisms gave higher cost: benefit ratio as compared to their single application. It was concluded that combined inoculation of BGA and *Azolla* with PSB and AM fungi along with a common dose of 90 kg N + 60 Kg K_2O ha^{-1} produced at par grain yield as produced due to the application of chemical fertilizer @ $N_{120}P_{60}K_{60}$. Significant response of BGA or *Azolla* inoculation with 90 kg N + 60 Kg K_2O ha^{-1} was found on yield and attributed of plant growth as evident from their better response compared to Azotobacter applied with same dose of chemical fertilizer. Plant growth, yield attributes and yield obtained with Azotobacter was significantly lower compared to other bio-inoculants. Response to single application of PSB and AM fungi was comparable to the response of BGA and *Azolla* application.

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Identification of barriers in adoption of farm mechanization technologies and strategies for its enhancement in Bundi district, Rajasthan

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ABSTRACT

The technological advancements in Indian agriculture have brought about revolutionary increase in agricultural production. The increased use of purchased inputs in agriculture necessitated to raise their use efficiencies through mechanization. Despite of promising opportunities of farm implements and machinery for farm operations, it potential is not being realized due to several constraints. A study was undertaken, in this context, to analyse constrains in agriculture for promoting mechanization of farming. It was observed that lack of information, small and scattered land holdings, limited resource and unavailability of appropriate machinery emerged major limiting factors to farm mechanization.

Key words : Barriers, farmer, farm mechanization

The technological advancements in Indian agriculture have brought about revolutionary increase in agricultural production. This has been made possible due to evolution of high yielding crop varieties, increased use of chemical fertilizers, development of irrigation facilities and plant protection measures. The increased use of purchased inputs in agriculture necessitated to raise their use efficiencies through mechanization. It can be argued that tools, implements and powered machinery, are essential, most important and major inputs to agriculture. The level, appropriate choice and subsequent proper use of mechanized inputs in agriculture has a direct and significant effect on achievable levels of agricultural production and the profitability of farming. Moreover, reliance on animate power for day to day management of farm operations is showing a continuous decline owing to higher and improved land and labour productivity resulting from use of mechanical power. Despite of promising opportunities of farm implements and machinery for farm operations, it potential is not being realized. The agriculture mechanization is constrained due to several factors. It is essential to formulate a package for adopting mechanization after conducting a thorough investigation. The present study is undertaken to analyse constrains in agriculture for promoting mechanization of farming.

MATERIALS AND METHODS

The study was conducted in Bundi district of Rajasthan. A constraints analysis of farm mechanization was undertaken to identify the factors responsible for the adoption gaps existing in the case of various farm implements and machines for farming. The major constraints to farm mechanization were identified by a pilot study. Based on the pilot study, eight major constraints were identified. The intensity of the identified constraints in the actual field situation was measured to prove their validity and to find out the extent to which they were perceived by farmers as barriers in adoption of various farm implements and machines for farming. All the eight constraints were measured by random interviewing five hundred farmers with the help of a well structured and pre-tested interview schedule developed for the study. The data thus collected were statistically analyzed.

The quantification of data was done by first ranking the constraints based on the responses obtained from the respondents and then calculating the rank based quotient (RBQ) (Sabarathnam, 1988), as follows:

$$R.B.Q. = \frac{\Sigma fi(n+1-i)}{N \times n} \times 100$$

Where,

fi = number of farmers reporting a particular problem under ith rank

N = number of farmers

n = number of problems identified

RESULTS AND DISCUSSION

Socio-economic profile of respondents

The socio-economic profile of respondent farmers is given in Table 1. The majority (51.8%) of the respondents belonged to middle age group followed by young age (34.0%) and old age (14.2%) group. While looking at their educational status, results revealed that majority (35.2%) of respondents were functionally literate (upto middle class) followed by high school (26.4%), illiterate (22.6%) and graduate and above (15.8 %).

It was observed that 60.6 per cent of the farmers fell under the category of low knowledge and only 26.8 per cent belonged to the category of medium knowledge and awareness of the availability of a suitable machine, tool, or implement, proper knowledge

Table 1. Socio-economic profile of respondents farmers (n=500)

Variables	Category	Frequency	Percentage
Age (in years)	Young (<30)	170	34.0
	Middle (31-50)	259	51.8
	Old (>50)	71	14.2
Education	Illiterate	113	22.6
	Functional literate (up to middle class)	176	35.2
	High school	132	26.4
	Graduate and above	79	15.8
Knowledge about farm machinery	Low	303	60.6
	Medium	134	26.8
	High	63	12.6
Resourcefulness	Rich	61	12.2
	Medium	187	37.4
	Poor	252	50.4
Credit utilization	Low	308	61.6
	Medium	133	26.6
	High	59	11.8
Holdings	Marginal	115	23.0
	Small	189	37.8
	Medium	127	25.4
	Large	69	13.8
Attitude towards mechanization	Favourable	243	48.6
	Neutral	138	27.6
	Unfavourable	119	23.8

to purchase, operation and maintenance of farm machinery. Majority of the respondent farmers were resource poor (50.4%) with low level of credit utilization (61.6%) had small size and scattered holdings (60.8%). It was interesting to note the majority of the respondent farmer favored (48.6%) the mechanization of agricultural operations even though their farm operations were observed partially mechanized.

Constraints

In order to take advantage of promising opportunities of farm implements and machinery for farm operations, the farmers need to overcome a number of impediments related to farm mechanization. In addition to some general constraints, farmers are being faced an array of specific constraints relating to farm mechanization. These constraints faced by the respondent farmers presented in Table 2 along with their ranks given by them. Based on the ranks, RBQ for each constraint was calculated and presented in Table 3.

Lack of information

The results presented in Table 3 indicated that unawareness of the availability of a suitable machine, tool, or implement and lack of proper knowledge about purchase, operation and maintenance of farm machinery was identified as the major constraint in farm mechanization and based on RBQ value it was given first rank. It was also observed from socio-economic profile of respondent farmers that they were unaware of the availability of a suitable machine, tool, or implement that could aid in their usually tedious work. They had a very little knowledge of operational efficiency of farm machinery, their source and purchase, operation and maintenance.

Small farm size

A small-sized farm was a big issue when it came to mechanization because this was against the principle of economies of scale. Small size and scattered holdings of the farmers stood in the way of mechanization. Based on RBQ value, small farm size was given third rank. The mechanization of small, non-contiguous parcels of land may prove to be inefficient. As a result of this, farm machinery generally remains underutilized. According to a report of the Project Planning and Monitoring Cell of the Government of Kerala (1986), the small farmers have little access to appropriate farm equipments, especially power machines. Similar constraints on farm mechanization were also reported by Prakash (1989).

Limited resource

Limited resources availability to and low credit utilization by farmers was also reported one of the major impediments to farm mechanization and given second rank on the basis of RBQ value. These farmers had limited resources and were unable to readily embrace technology. Even with the availability of credit

Table 2. Frequency distribution of ranks given by farmers to different constraints

Constraints	Ranks							
	I	II	III	IV	V	VI	VII	VIII
Lack of information	134	119	75	62	59	38	13	0
Small farm size	89	67	107	105	61	37	17	17
Limited resource	79	86	101	93	68	34	20	19
Unavailability of appropriate machinery	121	129	91	72	36	16	14	21
High initial cost	61	84	71	81	93	43	34	33
Complexity	9	0	23	43	67	84	127	147
Inadequate repair and service facilities	7	15	32	33	57	119	115	122
Poor extension support	0	0	0	11	59	129	160	141

from banks and non-banks, these were seldom patronized by farmers because of the fear of debt. Contributory factors to this fear may be high interest rate, long processing time, and sometimes, the requirement for collateral or a guarantor.

Unavailability of appropriate machinery

Non-availability of suitable farm implements and machines appropriate for small-scale application suitable to the local conditions was reported as one of the key factors limiting farm mechanization process. Even if as much as 80% of the farm power is provided by human beings, there is still a need to develop simple, manual equipment for various farm operations. James and Mohammed (1988) also identified lack of appropriate equipment to suit the regional requirements as one of the constraints to rice farm mechanization.

Complexity

Complexity of operating and repairing farm implements and machines observed another important determinants to farm mechanization by many farmers and given forth rank. Many farm implements and machines are complex to operate and repair and require a detailed understanding of processes. Complexity makes the innovation more difficult to understand, and generally requires greater management skills. The lack of repair and replacement facilities and lack of skilled labourers for operating improved farm implements and machines especially in the rural remote areas is another hindrance in efficient small farm mechanization. Similar constraint was also reported by Nikkade and Bhople (1989).

High initial and operational cost

Some farmers reported that purchase of many farm machines required high initial cost and high cost of operation of machines. There was great shortage of diesel and power supply in rural area. Thus, to use so expensive farm machinery was not desirable. Due to the seasonal nature of the agriculture, the farm machinery remains idle for much of the time. Thus, idle machinery means unnecessary high costs unless proper alternate use of such machinery in the off-season is made.

Poor extension support

Lack of extension system to integrate the mechanization technology into the total farming system was also raised as constraints to farm mechanization during the discussion with respondent farmers. Inadequate training facilities for farmer-users and artisans, inadequate service centers and lack of regulations on custom hiring services were cited chief bottlenecks of farm mechanization by Verma, et al. (1994).

Breaking down the barriers to farm mechanization

After identifying the major problems that hinder the transfer of mechanization technology, it was tried to identify strategies or to penetrate these barriers. On the basis of informal discussion with scientist, key informants and progressive farmers several steps has been suggested that could be taken up for encouraging mechanization of agriculture in Rajasthan in particular and country as whole in general.

Awareness creation and capacity building

A popular phrase is that "knowledge is power." Information is the key to making sound decisions. It is a fact that many farmers and extension workers are unaware of the availability of a suitable machine, tool, or implement that could aid in their usually tedious work. They lack of proper knowledge to purchase, operation and maintenance of farm machinery. This might secluded the farmers from

Table 3. Rank based quotient of constraints

Problems	R.B.Q.	Overall Rank
Lack of information	76.03	I
Small farm size	68.85	III
Limited resource	68.45	IV
Unavailability of appropriate machinery	75.45	II
High initial cost	62.73	V
Complexity	33.65	VII
Inadequate repair and service facilities	36.38	VI
Poor extension support	28.48	VIII

technology. Technical know-how should be provided to the farmers with respect to appropriateness of farm machinery for the situation and for its proper use. It is this information that we need to impart to our farmers so that they may be able to have better control of their lives. Information dissemination activities through media, displays, farmers' day, actual field demonstrations and the like, should be actively pursued where these are wanting. Popularized versions of training and technical materials in the local dialects would promote better understanding of these materials. A centralized information database for the farmers, linking all information concerning agricultural mechanization that can be accessed by farmers, extension personnel, scientists, engineers, students, and policy makers would greatly contribute to the transfer of the technology.

Training for farmers, manufacturers and extension agents

The education and training of farmers and operators are sometimes inadequate and need intensification. Local manufacture of agricultural machinery can be promoted through trainings on village-level craftsmanship, manufacturing technology, operation, repair, and maintenance. Local manufacturers can be provided with technical assistance in the fabrication of machine prototypes and devising smaller machinery suitable for small farms which constitute the vast majority of farmers but the machinery has to be effective and less costly. Extension agents should have ample time to learn a technology before they can effectively teach to others. If this is not realized, extension work would be like "the blind leading a blind." Extension personnel may need more training than our farmers to garner credibility.

Custom hiring of farming operations

The use of the machine, tool, or implement for custom hiring should be encouraged. Instead of buying their own machinery for their field operations, some farmers resort to custom hiring. Operations such as land preparation, sowing, harvesting, drying, are mostly available under such services. Payment can be in the form of cash or certain percentage of the harvest. This is currently a viable mechanization relationship between farmers and contractors. The custom service operation appears to be a workable strategy for promoting mechanization because it is based on a direct client-provider relationship governed by normal market forces.

Institutional support

Substantial institutional support by government organizations and non-government organizations to ensure availability of the widest choice of appropriate farm tools, machinery and equipment at affordable prices as well as access to spare parts and service to allow the farmer to make the best choice available to suit his own socio-economic and bio-physical situations. Credit and finance should be available for all sizes and types of farm operation.

Support for farmers' institutions

The farmers' groups or association should be encouraged which can provide services to their members and also lobby government on matters of farming interest.

CONCLUSION

Mechanization of agriculture is the need of the hour but it is constrained by several factors. The above analysis indicates that most of the negative factors against farm mechanization can easily be solved without much difficulty. The strategy proposed above in this paper could be helpful to strengthen mechanization to boost the agricultural production and productivity to stabilize the economy of farmers.

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Performance of wheat (*Triticum aestivum*)+linseed (*Linum sativum*) intercropping system as influenced by planting geometry and nutrient management

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ABSTRACT

A two year field experiment was carried out during 2007-08 and 2008-09 at Lakhaoti, Bulandshahr to study the performance of wheat and linseed under 4 intercropping systems viz. 1:1, 2:1, 4:1 row ratios along with pure stand of both the crops at 30 cm row spacing; and 4 fertility levels viz. 5t FYM/ha, N_{50} P_{30} K_{20} kg/ha (50% RDF), N_{75} P_{45} K_{30} kg/ha (75% RDF) and N_{100} P_{60} K_{40} kg/ha (100% RDF). The growth attributes of wheat *viz.* plant height and tillers in raw length were higher with pure crop of wheat followed by wheat in 4:1 ratio. The yield attributes *viz.* spikelets/ear and grains /ear; grain yield, stover yield and harvest index also showed the same trend. Application of 100% NPK (N_{100} P_{60} K_{40}) recorded significantly higher growth and yield parameters, yield, and harvest index in wheat as compared to other and fertility levels. The plant height of linseed was higher with 2:1 intercropping system, while the capsules /plant, seed/capsule, grain weight/capsule, grain yield, stover yield and harvest index were higher in pure crop of linseed. The 2:1 intercropping recorded higher seed yield, stover yield and harvest index among intercropping systems. Application of 75% NPK (N_{75} P_{45} K_{30}) recorded the highest capsules/plant, seed weight/capsule and 1000 seed weight, however, the application of 50% NPK (N_{50} P_{30} K_{20}) recorded the highest seed yield at par with 75 and 100% NPK application.

Key words : Intercropping systems, nutrient levels, linseed, wheat, yield

Wheat and linseed intercropping is a common practice in the dry land areas of Madhya Pradesh and Maharashtra, though this is done in other states of India on a smaller scale. Of the two crops intercropped, one is a cereal and another is oilseed and they differ in growth, both in time and space, and nutrient requirements. The nutrient needs will change in a mixed stand and is expected to be different than the two component crops tried in sole crops (Pareek, 1987). Although, a lot of work has been done on various aspects of sole cropping of wheat and linseed but information on their association is scanty. No information is available on the nature of crop competition and pattern of nutrient needs of the wheat and linseed cultivars grown in an intercropping system in the climatic conditions of western Uttar Pradesh. The imbalanced use of nutrients is widely prevalent in crops with very high use of N and less use of P and negligible use of K fertilizers. Wheat and linseed crops grown in inter cropping system using high yielding genotypes are highly nutrient responsive and the imbalanced and inadequate use of nutrients lead to their poor use efficiency. Balanced use of fertilizers and manures is the fore most important factor for increasing crop productivity as well as to sustain it over a longer period of time. As the mineral fertilizers alone can not meet the requirements of crops and cropping systems due to high cost and also environmental related risks involved in their application and uses, complimentary use of organics takes care of soil health and micronutrient deficiencies to a great extent. In view of the above facts, an experiment was carried out to study the effect of intercropping systems and fertility levels on the performance of wheat and linseed crops was attempted. This paper deals with the performance of wheat+linseed as influenced by the cropping systems and fertility levels.

MATERIALS AND METHODS

Field experiments were conducted at Crop Research Block, A.S. College, Lakhaoti, Bulandshahr, Uttar Pradesh for two consecutive *rabi* (winter) seasons of 2007-08 and 2008-09. The soil was well-leveled sandy loam in texture and slightly alkaline in reaction (pH 7.4). It analyzed low both in organic carbon (0.36%) and total nitrogen (0.035%). It was medium in available phosphorus (13.68 kg/ha) and potassium (162.6 kg/ha). Lakhaoti situated at 28.4°N latitude and 77.18°E longitude at 228.16 meters above the mean sea level, has semi-arid and sub-tropical climate characterized by hot-dry summers and cold winters. The treatments consisted of 4 intercropping systems of wheat and linseed viz. 1:1 (W_1:L_1), 2:1(W_2:L_1) and 4:1 (W_4:L_1), and 5 nutrient levels viz., 5t FYM/ha, N_{50} P_{30} K_{20} kg/ha (50% RDF), N_{75} P_{45} K_{30} kg/ha (75% RDF) and N_{100} P_{60} K_{40} kg/ha (100% RDF) alongwith pure crops of wheat (W) and linseed (L) with recommend practices totaling 18 treatments. The experiment was carried out in factorial randomized block design replicated thrice. Wheat ('UP 2348') and linseed ('Neelum') cultivars were sown in uniform rows of 30 cm as per the treatments. N, P and K were applied as per treatments. Phosphorus and potassium were placed 8-10 cm deep in line below the seed before sowing. The urea (N-46%) was used as a source of nitrogen and single super phosphate (P_2O_5 - 16%) and muriate of potash (K_2O - 60%) as source of phosphorus and potassium, respectively. The placement was done through iron pipe (*pora*) attached to the bullock drawn country plough. The fertilizer (N + P +K) was distributed in the plots uniformly to make it available to both the components. Well-decomposed FYM as per treatments was applied before 15 days of sowing. The cropping systems were achieved through careful management of row ratios at the time of sowing. The crops were normal in both the years of experiment with out any severe effect of any of the climatic effects. All the observations recorded were statistically analyzed as per the analysis of variance technique and the treatment differences were worked out at 0.05 probability.

RESULTS AND DISCUSSION

Wheat

Wheat in a pure stand performed better and registered higher plant height (Table 1), higher number of tillers/ m row length. The values of these characters decreased significantly in intercropping with linseed in different row proportions. In general, maximum reduction for wheat was observed in W_1:L_1. These characters in wheat improved significantly up to 100% NPK level i.e. N_{100} P_{60} K_{40} kg/ha. This may attributed least competition in pure crop of wheat as compared to intercropped wheat and increased availability of nutrients with 100% RDF. As wheat is highly exhaustive crop, optimum dose of nutrients is necessary for full expression of potential growth. Kumar *et al.* (2001) have also reported increased growth attributes of wheat due to 100 kg and 60 kg P_2O_5.

The yield attributes viz. ears/plant, spikelets/ear, grains/ear, ear length and its weight and grain weight/plant and test weight in wheat were higher in pure stand in both the seasons. In intercropping systems, the values of these attributes reduced significantly. In wheat, W_4:L_1 recorded least reduction. Application of 100% NPK recorded significant improvement inyield attributes in wheat over the lower levels. The yield attributes are manifested by improved growth attributes and continued supply of growth parameters like solar radiation, nutrients and water. Since there was least competition for solar radiation in 4:1 row ratio as compared to other ratios and also 100% RDF provided regular supply of nutrients, these treatments showed their superiority over other treatments.

Grain and straw yields and harvest index of wheat were more in pure crop. Inter cropping systems recorded a marked reduction in these parameters in both the crops. The W_4:L_1 system had lowest reduction in wheat. In inter cropping system, the reduction in population leads to decreased yield. Ahlawat *et al.* (2005) also

Table 1. Effect of cropping systems and fertility levels on the growth and yield attributes productivity of wheat (Mean of 2 years)

Treatment	Plant height (cm)	Tillers/ m row length	Ear length (cm)	Spikelets /ear	Grains /ear	1000 grain weight (g)	Grain yield (kg/ha)	Straw yield (kg/ha)	Harvest index (%)
Cropping systems									
W (pure)	80.1	114.2	8.4	11.9	25.7	48.3	3688	4859	43.1
W_1:L_1	76.9	108.3	8.4	11.1	23.8	47.3	2785	3998	41.1
W_2:L_1	78.7	110.3	8.2	11.6	24.5	47.3	3027	4075	42.6
W_4:L_1	79.3	114.1	8.3	11.4	25.4	47.9	3499	4305	43.2
SEm±	0.36	0.78	0.09	0.13	0.19	0.51	56	62	0.24
C.D. (P=0.05)	1.02	2.24	0.14	0.08	0.55	0.22	167	179	0.69
Nutrient levels									
5t FYM/ha	76.0	101.1	7.9	10.7	21.7	44.6	2871	3981	41.9
N_{50} P_{30} K_{20}	78.2	104.6	8.2	11.2	23.6	45.5	3057	4256	41.8
N_{75} P_{45} K_{30}	80.1	117.5	8.5	11.9	26.0	49.7	3390	4610	42.2
N_{100} P_{60} K_{40}	80.5	123.8	8.7	12.0	28.1	51.1	3681	4805	43.4
SEm±	0.36	0.78	0.09	0.13	0.19	0.51	56	62	0.24
C.D. (P=0.05)	1.02	2.24	0.25	0.38	0.55	1.47	162	179	0.69

reported similar results in mustard + chickpea inter cropping system. With least reduction in 4:1 row ratio it recorded higher yield as compared 1:1 or 2:1 row ratio, while pure crop recorded the highest yield. Application of fertilizers recorded significant increase in the yield of wheat up to 100% NPK level. This is mainly due to continued supply of N, P and K in optimum quantity as compared to lower levels of these nutrients.

Linseed

Plant height of linseed was not significantly affected by the cropping systems. It may due to its hardy nature and ability to cope with the competition. The capsules/plant, seeds/capsule, grain weight/capsule were higher in pure linseed as compared to intercropped linseed, indicating competition effect on yield attributes to some extent. Among the intercropping systems, 2:1 intercropping system recorded higher capsules/ plant, seeds/capsule and 1000 seed weight indicating the competition was less in this system. The grain yield and stover yield were higher in pure crop of linseed followed by 1:1 intercropping system with wheat. As the yield is the function of plant population, the optimum plant population in linseed in pure crop followed by 50% plant population in 1:1 row ration, recorded obviously higher yield as compared to rest of the intercropping systems.

Among the nutrient levels, 5 t FYM/ha recorded the lowest plant height, yield attributes and yield of linseed indicating it could not meet the nutrient requirement of the linseed. Although the yield varied in their response to nutrient levels, application of 50% RDF (N_{50} P_{30} K_{20}) recorded higher seed yield, stover yield and harvest index. These values being at par with higher levels of nutrients, indicated that the linseed is less nutrient requiring as compared to wheat. Atar Singh and Turkhede (1989) and Badiyala and Kumar (2003) also reported similar findings.

Table 2. Effect of cropping systems and fertility levels on the growth and yield attributes productivity of linseed (Mean of 2 years)

Treatment	Plant height (cm)	Capsules/ plant	Seeds/ capsule	Seed weight/ capsule	1000 seed weight (g)	Seed yield (kg/ha)	Stover yield (kg/ha)	Harvest index (%)
Cropping systems								
W (pure)	69.3	55.1	7.4	1.7	6.3	1224	4363	21.9
W_1:L_1	70.1	9.5	6.3	0.5	6.5	331	1431	18.8
W_2:L_1	69.1	12.6	6.4	0.5	6.6	206	850	19.5
W_4:L_1	69.9	7.7	6.2	0.4	6.5	171	661	20.6
SEm±	0.33	0.08	0.06	0.07	0.02	20	17	0.63
C.D. (P=0.05)	0.96	0.31	0.17	0.18	0.04	57	50	1.84
Nutrient levels								
5t FYM/ha	67.4	18.5	5.9	0.6	6.3	429	1648	20.6
$N_{50}P_{30}K_{20}$	70.2	20.9	7.0	0.8	6.5	500	1830	21.1
$N_{75}P_{45}K_{30}$	71.0	24.6	6.8	0.9	6.6	482	2037	19.3
$N_{100}P_{60}K_{40}$	72.1	21.1	6.4	0.8	6.4	486	1929	20.1
SEm±	0.33	0.08	0.06	0.07	0.02	20	17	0.63
C.D. (P=0.05)	0.96	0.31	0.17	0.11	0.04	57	50	NS

In view of the results, it may be concluded that, the planting of wheat in 4:1 row ratio along with 100% NPK ($N_{100}P_{60}K_{40}$ kg/ha) and linseed in 1:1 row ratio along with 50% NPK results in higher yield of wheat and linseed, respectively. However, the economics based the cost of inputs, market prices of crops would be necessary for arriving at ideal intercropping ratio and nutrient level for the intercropping system. Application of nutrients through only FYM may not be able to meet the nutrient requirement of either of the crops in wheat+linseed intercropping system.

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Effect of organic and inorganic sources of nutrients on growth, yield, quality and nutrient uptake by baby corn (*Zea mays*)

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ABSTRACT

Field experiment was carried out on sandy loam soil at Varanasi during *kharif* season of 2004 and 2005 to evaluate appropriate fertility levels and N sources for baby corn (*Zea mays* L.). Experiment was laid out in split-plot design and replicated thrice with three fertility viz. 60 -12.9 -24.9, 120 - 25.8 -49.8, 180 -38.7-74.7 kg N-P-K/ha in main plots and three N sources viz. 100% inorganic N, 75% inorganic N + 25% organic N, and 50% inorganic N + 50% organic N in sub plot. Significant increase in plant height, LAI, dry matter/plant, chlorophyll content and quality parameters *viz.*, starch, protein, sugar content in baby corn was recorded upto 120-25.8-49.8 kg N-P-K /ha. Yield of baby corn (2.63 t/ha), green fodder (43.85 t/ha), net returns (Rs 123989) and NPK uptake were recorded significantly higher at 180-38.7- 74.7 kg N-P-K/ha over 120-25.8-49.8 and 60-12.9-24.9 kg N-P-K/ha. Application of 100% inorganic N recorded significantly higher plant height, LAI, dry matter/plant, chlorophyll content, yield of baby corn (2.30 t/ha) and green fodder (38.53 t/ha), net returns (Rs. 1,10983/ha) and NPK uptake over 50% inorganic N + 50% organic N. Available N, P and K in the soil after baby corn harvest were highest with 180-38.7-74.7 kg N-P-K/ha and 50% N supplied through FYM.

Key words : Baby corn, growth, integrated nutrient supply, nutrient uptake, quality, yield

Baby corn (*Zea mays* L.) is immature dehusked, unfertilized maize ear, harvested 1 to 2 days after silking at 2-3 cm long silk stage are consumed as vegetable due to its sweet flavour. High nutritional value, eco-friendly and crispy nature of baby corn has made it special choice for various traditional and continental dishes apart from canning in the elite society (Singh *et al.*, 2006). After the harvest of babies, the economic potential is further enhanced since it supplies green, soft, succulent, nutritious, palatable fodder with higher digestibility. Recently cultivation has started and gaining popularity in peri-uraban areas due to its export potential to earn foreign exchange besides huge employment generation. Being a short duration crop (50-60 days) it can be sown and harvested 3 to 4 times in an year. Baby corn is nutrient exhaustive, planted at high density which required heavy nutrient application therefore, integrated nutrient management (INM) practices is important to get maximum benefit. To cope-up with the situation, the use of organic and inorganic sources of nutrients was taken to evaluate the varying levels of nutrients with and without organic sources on soil health and crop yield.

MATERIALS AND METHODS

Field experiment was conducted to study the effect of organic and inorganic sources of nutrients on growth, yield, quality and nutrient uptake on baby corn in *kharif* seasons of 2004 and 2005 at Agricultural Research Farm, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi. The farm is situated at 25°18'N longitude, 83°03'E latitude and at an altitude of 78.1 m above mean sea level. The sandy-loam soil of the experimental field was low in organic carbon (0.32%) and available N (219.6 kg/ha), medium in available P (18.81 kg/ha) and K (189.7 kg/ha) content, having pH 7.4. The experiment was laid out in split-plot design replicated thrice with 3 fertility levels *viz.*, 60-12.9-24.9 kg N-P-K/ha, 120-25.8-49.8 kg N-P-K/ha and 180-38.7-74.7 kg N-P-K/ha in main plots and 3 nitrogen sources viz. 100 % inorganic N, 75 % inorganic N + 25 % organic N(FYM), and 50 % inorganic N + 50 % organic N (FYM) in sub plots. Baby corn 'MRM- 3824' seeds @ 40 kg ha-1 were sown on leveled soil by opening 5 cm deep furrow at 40 cm x 20 cm spacing. Experimental crops were sown on 19 and 20 May in 2004 and 2005, respectively. The crop received 347 mm rain fall in first year and 273 mm rainfall in second year. Farm yard manure (0.45- 0.2-0.5% N-P-K) was used as an organic source of nitrogen and applied as per treatment. Full dose of FYM, P and K, and half dose of N were applied as basal by side dressing. Remaining half dose of nitrogen was top dressed at knee high stage. For recording days to baby corn production, the crop was regularly watched from 45 days after sowing. The immature cobs (baby corn) were harvested at 2-3 days of silk emergence. Treatment wise 7-8 pickings were done over a period of 14-16 days. These baby corns were counted, weighted and thereafter husked and silk was removed and baby corn yield was recorded. Crop was harvested on 2nd and 3rd August, in 2004 and 2005, respectively. The price of inputs like FYM@ Rs 0.50 kg^{-1}(dry weight) and produces, baby cob@ Rs 10 kg^{-1} and green fodder @ Rs 30 q^{-1} was taken for calculation of economics. Physico-chemical properties of soil, nutrients content and uptake by baby corn plants were analyses as per standard procedures.

RESULTS AND DISCUSSION

Growth parameters

The successive increase in the fertility caused an improvement in the plant height, leaf area index, chlorophyll content (SPAD) and dry matter accumulation /plant (Table1) up to maximum fertility level of 180-38.7-74.7 kg N-P-K/ha which was remained at par to 120-25.8-49.8 kg N-P-K/ha. But both treatments were registered significant in respect to above growth characters over 60-12.9-24.9 kg N-P-K/ha. This was the result of higher fertility which supplied better nutrition to short duration baby corn plants resulted in more growth of baby corn plants (Sahoo and Panda 1997 and Verma *et al.* 2006).

The effect of nitrogen sources on growth characters *viz.* plant height, leaf area index, chlorophyll content and dry matter /plant were significant. The application of 100 % inorganic N recorded maximum values of above growth characters which were significantly higher than 75% inorganic N + 25% organic N (FYM), and 50 % inorganic N + 50 % organic N (FYM). The effect of inorganic source on growth characters of baby corn was more pronounced due to rapid availability of plant nutrients (NPK) to short duration baby corn plants. Similar results were also reported in sorghum by Gawai and Panwar (2006).

Yield attributes and yield

Yield attributes and yield of baby corn were affected significantly due to fertility levels (Table 1). Significant reduction in the barren plants (%) was observed up to maximum fertility level of 180-38.7-74.7 kg N-P-K/ha. Significant increase in baby cob weight/cob, cobs/plant, baby corn girth, baby cob yield, baby corn and green fodder yield were observed with application of 180-38.7-74.7 kg N-P-K/ha as compared to lower levels of fertility 120-25.8-49.8 kg N-P-K/ha and 60-12.9-24.9 kg N-P-K/ha. Higher fertility level supplied luxury nutrition (NPK) to short duration baby corn plants resulted better growth and development viz plant height, LAI, dry matter and chlorophyll content etc. which produced higher yield attributes and yield (Sahoo and Mahapatra, 2007). The baby cob: corn ratio was found to increase with each increase in fertility level but it did not differ significantly.

Yield contributing characters of baby corn were influenced significantly by the application of nitrogen sources (Table 1). Significantly superior values of yield attributes and yield *viz.* baby cob weight /cob, cobs/plant, baby corn girth, and yield of baby cob, baby corn and fodder were recorded with application of 100% inorganic N over integrated nutrients applied as 50% inorganic N + 50% organic N and 75 % inorganic N +25 % organic N. Raghuwanshi and Umat (1994) reported higher yield and yield

Table 1. **Effect of integrated nutrient supply on growth characters, yield and yield attributes of baby corn (pooled data of 2 years)**

Treatments	Growth characters					Yield attributes							
	Plant height (cm)	LAI	Dry matter (g plant^{-1})	Chloro-phyll (SPAD)	Barren plant (%)	Baby cobs /plant	Baby cob weight (g/ plant)	Baby corn length (cm)	Baby corn girth (cm)	Baby corn :baby cob (ratio)	Baby cob yield (t/ha)	Baby corn yield (t/ha)	Fodder yield (t/ha)
Fertility levels (N-P- K kg / ha)													
60-12.9-24.9	181.43	5.63	147.67	40.62	7.57	1.82	32.02	8.62	3.08	4.72	6.73	1.44	25.01
120-25.8-49.8	214.08	6.23	184.79	44.07	5.52	2.61	36.77	9.35	3.75	4.81	11.32	2.33	38.00
180-38.7-74.7	222.54	6.46	200.45	45.43	3.64	2.96	39.44	9.68	4.25	5.02	13.12	2.63	43.85
SEm	4.54	0.11	5.37	0.63	0.19	0.07	0.81	0.16	0.10	0.21	0.34	0.06	1.17
CD (P=0.05)	17.83	0.42	20.51	2.47	0.76	0.29	3.15	0.56	0.40	NS	1.35	0.23	4.51
Sources of N application (% inorganic+% organic)													
100 + 0	214.99	6.34	190.74	45.39	4.94	2.61	37.69	9.38	3.85	4.90	11.58	2.30	38.53
75 + 25	205.21	6.10	176.72	43.25	5.61	2.46	36.26	9.19	3.70	4.91	10.35	2.15	35.47
50 + 50	197.84	5.88	165.85	41.47	6.18	2.32	34.28	9.09	3.54	4.75	9.24	1.95	32.74
SEm	2.66	0.07	2.46	0.64	0.11	0.04	0.47	0.13	0.05	0.09	0.15	0.04	0.48
CD (P=0.05)	8.20	0.22	7.65	1.98	0.34	0.12	1.46	NS	0.14	NS	0.46	0.15	1.47

attributes with 100 % inorganic fertilizers than 50 % inorganic N+50% organic N. Baby cob: baby corn ratio did not differ significantly but was highest with application of 100 % inorganic N. A significant reduction in barren plant (%) were observed with 100 % inorganic N which increased by increasing proportion of organic N (FYM) with 50% inorganic N + 50% N as FYM, due to its slow nutrient release pattern (Sahrawat, 2006) could not supply sufficient N at critical growth stages of plants resulted lower yield.

Interaction

Interaction between fertility levels and N sources on baby corn and fodder yield was found significant (Table 2). Application of 180-38.7-74.7 kg N-P-K/ha through 100% inorganic N recorded highest baby corn and green fodder yield which was significantly superior to all remaining treatments except 180-38.7-74.7 kg N-P-K/ha applied as 75% inorganic N + 25% organic N, was at par. It was due to adequate and rapid availability of nutrients by fertilizer source at higher fertility level. Further, the data indicates that application of 100% inorganic N produced highest baby corn and green fodder yield at each fertility level.

Quality parameters

The quality parameters viz. protein, starch, reduced sugar and non-reduced sugar content in baby corn was significantly higher with application of 180-38.7-74.7 kg N-P-K/ha than lower fertility of 60-12.9-24.9 kg N-P-K/ha but remained at par with medium fertility at 120-25.8-49.8 kg N-P-K/ha. (Table-3). Since N, P and K involved in physico-chemical reactions in plant body of baby corn did behave accordingly to their effect on plant system and enhanced the values of quality parameters. Ramachandrappa et al. 2004 reported similar response in baby corn with higher fertility level. Higher values of protein, starch and sugars were recorded with application of 100 % inorganic N as compared to integration of both inorganic and organic N. This was due to rapid availability of applied nutrients to the plants. Although, organic N source is the store house of nutrients but there slow nutrient release pattern to the short duration baby corn plant resulted comparatively lower values of above quality parameters. Saha and Mondal (2006) noticed similar results in baby corn.

Nutrient Uptake

Nutrient uptake by baby corn plant (baby corn + green fodder + husk) was affected significantly due to fertility levels and sources of N (Table 3). The uptake of N, P and K plants increased significantly with successive increase in fertility level, which led to maximum N, P and K uptake at 180-38.7-74.7 kg N-P-K/ha, was significantly higher than that of 120-25.8-49.8 kg N-P-K/ha and 60-12.9-24.9 kg N-P-K/ha. This increase was mainly due to increased green cob and fodder yield assured greater uptake of nutrients (NPK). The findings of Saha and Mondal (2006) confirmed the results. Significantly

Table 2. Interaction effect of fertility levels and nitrogen sources on baby corn yield and green fodder yield (pooled data of 2 years)

Treatment	Baby corn yield (t/ha)			Green fodder yield (t/ha)		
	S_1	S_2	S_3	S_1	S_2	S_3
F_1	1.60	1.44	1.27	27.92	25.06	22.21
F_2	2.50	2.35	2.13	41.05	37.57	35.32
F_3	2.81	2.65	2.45	47.05	43.79	40.69
S Em S at same level of F			0.07		1.15	
CD (P=0.05)			0.19		2.96	
S Em F at same or different level of S			0.08		1.26	
CD (P=0.05)			0.25		3.92	

S_1: 100 % inorganic; S_2: 75 % inorganic +25% organic; S_3: 50 % inorganic +50% organic

Table 3. **Effect of integrated nutrient supply on economics, nutrient uptake by baby corn and soil fertility status after harvest (pooled data of 2 years)**

Treatments	Starch (%)	Protein (%)	Reduced Sugar (%)	Non-reduced sugar (%)	Cost of culti-vation (Rs/ha)	Net return (Rs/ha)	B: C ratio	Nutrient uptake (kg/ha)			Available nutrients after 2 year (kg/ha)		
								N	P	K	N	P	K
Fertility levels (N-P-K kg/ha)													
60-12.9-24.9	61.52	15.97	0.27	61.52	23871	55917	2.32	82.92	17.77	90.19	188.42	21.26	138.99
120-25.8-49.8	64.99	18.25	0.43	64.99	26526	105620	3.81	135.35	35.04	151.71	211.17	22.86	157.83
180-38.7-74.7	67.93	19.27	0.45	67.93	29179	123989	3.96	168.23	49.44	217.00	230.88	24.02	168.86
SEm	1.55	0.58	0.01	1.55	896	2890	0.115	5.62	1.59	6.98	3.97	0.44	3.13
CD (P=0.05)	5.90	2.26	0.04	5.90	3518	11347	0.45	22.05	6.24	26.91	15.60	1.72	12.27
Sources of N application (% inorganic+% organic)													
100 + 0	65.79	18.04	0.41	2.53	24157	110983	4.24	141.81	41.37	176.39	197.42	21.07	143.29
75 + 25	65.15	17.82	0.38	2.50	26459	94728	3.45	128.32	34.17	150.45	210.77	22.85	152.83
50 + 50	63.51	17.63	0.36	2.42	28959	79816	2.7	116.38	26.72	132.06	222.27	24.22	169.57
SEm	1.19	0.31	0.02	0.04	475	2209	0.08	2.67	0.87	3.71	3.31	0.32	2.25
CD (P=0.05)	NS	NS	0.05	0.11	1464	6809	0.26	8.24	2.67	11.42	7.21	0.70	4.92
Initial status											219.60	18.80	189.75

higher nutrients uptake (NPK) were recorded with the application of 100% inorganic N over 50% inorganic +50% organic N, and 75% inorganic N+ 25% organic N). This was due to higher yield of baby cob and fodder yield along with higher nutrient content in 100% inorganic N applied plants.

Economics

Net return and B:C ratio increased significantly with each successive increase in fertility level which were highest (Rs 1,23,989 and 3.97) with application 180-38.7-74.7 kg N-P-K/ha(Table- 3). That was due to significantly higher baby corn and green fodder yield at higher fertility level (Sahoo and Mahapatra, 2005).

Application of 100% inorganic N recorded significantly higher net return and B: C ratio (Rs 1,23,989 and 4.25) than integrated nutrient supply as 75% inorganic N + 25% organic N, and 50 inorganic N + 50% organic N. The higher baby corn and green fodder yield with 100% inorganic N source led to higher net return and B: C ratio.

Soil fertility status

Available nutrient in the soil after harvest of 2nd crop were affected significantly due to fertility levels and sources of N (Table 3). Significant variation in available N, P and K in the soil was observed with each successive increase in fertility level and being highest with application of 180-38.7-74.7 kg N-P-K/ha. The balance of N, P and K over initial soil fertility was 5.10, 27.7 and -8.9 %, respectively with application of 180-38.7-74.7 kg N-P-K/ha. With increase in the level of fertility (N, P and K) also assured the availability of these nutrients to the crop plants in adequate amount and remained in soil in substantial quantity after fulfilling the crop requirement that ultimately improved the soil fertility (Saha and Mondal, 2006).

Significantly higher values of available N, P and K in soil were recorded when integrated nutrients applied as 50% inorganic N + 50% organic N over 75% inorganic N + 25% organic N, and 100 % inorganic N. The balance of N, P and K over initial soil fertility was 1.2, 28.87 and -9.0 %, respectively with application of 50% inorganic N + 50% organic N). It might be due to direct addition of partial N through FYM and greater multiplication of soil microbes, which convert organically bound N to inorganic form. The increase in P content may be ascribed to the capacity of farmyard manure to form a cover of sesquioxide which reduces the phosphate fixation. The availability of K might be due to addition of K to the available pool of the soil. Another reason may be short duration baby corn crop, could not fully utilize the applied nutrients and remained left in the soil. Similar findings are also reported by Gawai and Pawar (2006).

It can be concluded that application 180-38.7-74.7 kg N-P-K/ha through 100% N as inorganic (fertilizer) or 75% N as inorganic + 25% organic N (FYM) was promising for yield, quality and net return of baby corn.

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Effect of FYM and sodic irrigation water on oat (*Avena sativa* L.) Crop

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ABSTRACT

An experiment was conducted in an alkaline alluvial soil to test the suitability of graded level of RSC (5, 10, 15, and 20 me/l) and FYM levels (5, 10 and 15 t/ha) on fodder crop (*Avena sativa* L.). Green foliage yield reduction was highest (51%) at RSC of 20me/l and 31, 20 and 12% with 15, 10 and 5me/l of RSC, respectively over control. The interaction effect between RSC and FYM was significant. Green foliage yield of oat was increased significantly with increasing levels of FYM. Green foliage yield was significant up to 10 me/l of RSC in combination with FYM @ 15 t/ha. Other yield attributes were also significantly improved with FYM application, while they were adversely affected by high RSC.

Key words : FYM, RSC irrigation water, oat, uptake of nutrients, soil fertility

In recent years feeding of livestock population (343.7 million) has created an acute imbalance between fodder resources and the number of animals as is evidenced by the livestock and availability of feeds and fodder Arora (1980). In India, where oat (*Avena sativa* L.) cultivation offers great scope, the animal food is one of the most important practice, which plays significant role in improving the quality and quantity of milk. Oats are an extremely versatile Rabi (winter) cereal fodder crops in India. It can be grown on wide range of environments on diverse soil types for forage and as a companion crop. It is a quick growing, palatable, succulent and nutritious crop. It is rich in energy, protein, vitamin B, phosphorus and iron Mehta, (1978). This crop is used as a green fodder; hay, silage and its grain make good concentrate for livestock. Area under oat cultivation (world) is approximately 17166 thousand hectare with production of 32840 thousand million tones. About 952 million ha land with world and 7.1 million ha of land in India is affected by salinity and alkalinity FAO/UNESCO, (1974). Saline and alkaline soils occur extensively in arid and semiarid region Abrol *et al*, (1988). About 1.3 million ha land affected by salinity and alkalinity in eastern India. Plant growth is inhibited under such condition due to unfavorable pH, excessive salt and imbalance of nutrient and poor soil structure. Soil sodicity through irrigation create problem for fodder cultivation. The present study was therefore undertaken to assess the effect of sodicity through irrigation water and FYM levels on oat crop.

MATERIALS AND METHODS

The experiment was conducted in the department of agricultural chemistry and soil science, R.B.S. College, Bichpuri, Agra during *Rabi* seasons of the years 2003 and 2004. This experimental site is located between 27.2° N latitude and 77.9° E longitudes characterized as semi-arid agroclimate ecoregion. Under average climatic condition over the years, the area received 675 mm rainfall annually. The average monthly maximum and minimum atmospheric temperatures were 45°C and 10°C, respectively. The soil of the experimental site was sandy loam (Ustifluvent). The pot experiment was laidout with three levels of FYM and five levels of Residual Sodium Percentage (RSC) in factorial

RBD with three replications. The RSC levels viz 0, 5, 10, 15 and 20me/l and FYM viz 0, 5, 10, 15 and 20.0 t/ha were studied under pot experiment. The composite soil sample was taken from the experimental soil before sowing and subjected to the analysis for physico-chemical characteristics is given in Table 1.

The earthen pots lined with polyethylene sheet were filled with 5 kg soil. Recommended doses of N, P and K fertilizers were applied at the rate of 120, 60 and 60 kg ha^{-1} respectively. The source of N, P and K was from urea, single super phosphate and murate of potash, respectively. Organic matter was applied in the form of well decomposed FYM at the rate of 5, 10 and 15 t/ha (F_0, F_1, F_2 and F_3) respectively. The sodic water was prepared by dissolving $NaHCO_3$ salt in distilled water to get the desired the RSC (Residual Sodium Percentage) value 0, 5, 10, 15 and 20 me/l (S_1, S_2, S_3, S_4 and S_5) respectively. The plants were irrigated with number of specified treatments after germination up to three months. After harvesting the plant sample were air dried followed by oven drying at 70°C ground in a Wiley mill. Homogenized plant samples were analyzed for nitrogen Snell and Snell, (1955), phosphorus, potassium, sodium, calcium and magnesium Jackson, (1973) and zinc using standard methods.

Table 1. Physico-Chemical characteristics of the experimental soil

Soil characteristics	Value
Mechanical analysis	
(a) Sand (%)	68.95
(b) Silt (%)	16.01
(c) Clay (%)	15.60
Textural class	Sandy loam
EC (ds^{-1} at 25°C)	3.4
pH (1:2.5 soil: water suspension)	8.2
Organic carbon (%)	0.45
Water soluble cat ions (me/l)	
(a) Ca^{++}	6.13
(b) Mg^{++}	7.85
(c) Na^{++}	15.95
(d) K^{+}	0.23
Water soluble anions (me/l)	
(a) CO_3^{-}	Nill
(b) HCO_3^{-}	8.38
(c) Cl^{-}	11.30
(d) SO_4	11.32
Exchangeable sodium percentage	9.8
Available Nitrogen (kg/ha)	189.85
Available phosphorus (kg/ha)	18.2
Available potassium (kg/ha)	235.0
Available zinc ($kgha^{-1}$)	3.0

After harvesting, soil samples were taken from each pot, air-dried, ground in wooden pestal and mortar. Passed through 2 mm sieve and stored in polythene bags for further analyses. pH, electrical conductivity of the saturation extract was determined by using a glass combined electrode (soil: water ratio 1: 2.5), RSC following Richard, (1954), organic carbon Walkley and Black, (1934), available N, P and K by the method of Subbiah and Asija (1956), Olsen et. al., (1954) and by flame Photometer, respectively. DTPA extractable Micronutrients were analyzed by atomic absorption spectrophotometer (GBC Australian model) by using the procedure of Lindsay and Norvell (1978).

RESULTS AND DISCUSSION

Yield and growth attributes

A higher RSC level (S_5) both during *Rabi* 2003 and 2004 yield and all yield attributes decreased and the effect was significant as compared to control treatment. On the control plant height and number of leaves per plant, were significantly higher in F_3 treatment (FYM) as compared to lower levels of FYM. It is evident from the data given in Table 2 that average plant height increased by 7.56, 14.91 and 24.37 percent with F_1, F_2 and F_3 levels of FYM over control, respectively. Similarly the plant height increased by 7.86, 14.30 and 23.68 percent with F_1, F_2 and F_3 levels of FYM over control during *Rabi* 2004. Further it was indicated that significantly more dry weight at each cutting of oat was obtained with F_3 (FYM) in comparison to F_0, F_1, and F_2 levels of FYM during both the years. The results are in agreement with those of Ravankar *et al.*, (2005) and Swarup and Yaduvanshi (2000), Pal *et al.*, (1993), Yadav *et al.*, (2002) and Singh *et al.*, (2005) also noted the reduction in plant height

Table 2. The plant height (cm), no. of leaves/plant and dry matter yield (g/pot) of oat as influenced by RSC and FYM levels

Treatment RSC Levels	Plant Height (cm) Mean		No. of leaves/ plant Mean		Dry matter yield (g/pot) Mean	
	2003	2004	2003	2004	2003	2004
S_1	36.03	36.47	16.32	16.67	3.88	4.31
S_2	32.88	33.36	15.78	16.06	3.42	3.57
S_3	29.40	29.77	15.22	15.50	3.19	3.30
S_4	26.69	27.10	15.07	15.15	2.81	2.95
S_5	21.15	21.55	14.23	14.53	1.82	1.96
SEm±	0.031	0.034	0.021	0.023	0.045	0.039
L.S.D. (P=0.05)	0.092	0.098	0.063	0.069	0.0129	0.010
FYM Levels						
F_0	46.35	37.11	17.15	17.37	4.28	4.45
F_1	39.10	40.03	19.17	19.37	4.78	4.90
F_2	41.77	42.42	21.60	21.74	5.47	5.65
F_3	45.21	45.90	24.41	24.56	6.21	6.69
SEm±	0.032	0.032	0.021	0.022	0.004	0.038
L.S.D. (P=0.05)	0.094	0.096	0.063	0.066	0.013	0.010

and increased the numbers of leaves with increasing levels of RSC water.

Data given in Table 2 reflects that the pooled dry weight of oat decreased significantly with increasing RSC of irrigation water in both the years. Significantly higher reduction in dry weight was recorded at higher RSC level (S_5). Treatments S_2, S_3, S_4 and S_5 levels showed 11.85, 17.78, 27.57 and 58.09 percent reduction in dry weight, respectively over control. Similarly the S_2, S_3, S_4 and S_5 RSC levels resulted 17.16, 23.48, 31.55, and 54.52 per cent reduction in dry weight respectively over the control (S_1). Similar results were also reported by Singh *et al*, (2005).

Nutrient Contents

Data presented in Table 3 reviles that the levels of RSC significantly influenced the nutrient content of oat. Higher levels of RSC significantly decreased the nitrogen content at each cutting of oat. The results are in agreement with the findings of Chauhan *et al.* (1989); Pal *et al.* (1993) and Singh *et al.* (2005).

The significant reduction in phosphorus content was observed with S_4 and S_5 level of RSC. Phosphorus content was higher in F_3 level of FYM treatment and the useful effect of FYM was noted by Swarup and Yaduvanshi (2004). Our findings are in accordance with those of Pal *et al.* (1993) and Singh *et al.*, (2005).

Except S_2 level of RSC during *rabi* 2003 and all RSC levels decreased significantly the potassium content of oat. Higher level of RSC of irrigation water significantly lowered the potassium content in comparison to preceding lower levels of RSC. The reduction was higher S_5 treatment. Regarding FYM levels of F_3 maintained higher potassium content as compared to F_0, F_1 and F_2 levels.

Calcium content at each cutting of oat decrease significantly at S_5 level of RSC over other RSC levels in both the years. F_3 level of FYM maintained significantly higher calcium content as compared to F_0, F_1 and F_2 levels. Similar trend was also reported by Swarup and Yaduvanshi (2004).

Each higher level of RSC of irrigation water decreased significantly the magnesium content of oat. The FYM (F_3) treatment showed significantly higher magnesium content as compared to F_0, F_1 and F_2 level of FYM.

Table 3. N, P, K, Ca, Mg and Na content (%) in oat as influenced by RSC and FYM levels

Treatment	N (%) Mean		P (%) Mean		K (%) Mean		Ca (%) Mean		Mg (%) Mean		Na (%) Mean	
RSC Levels	2003	2004	2003	2004	2003	2004	2003	2004	2003	2004	2003	2004
S_1	1.75	1.76	0.24	0.23	1.49	1.51	1.33	1.31	0.695	0.702	0.26	0.26
S_2	1.66	1.67	0.23	0.24	1.49	1.46	1.30	1.29	0.686	0.658	0.27	0.28
S_3	1.42	1.44	0.22	0.21	1.47	1.46	1.28	1.28	0.674	0.672	0.28	0.28
S_4	1.21	1.22	0.20	0.18	1.45	1.45	1.26	1.25	0.665	0.665	0.29	0.30
S_5	1.09	1.10	0.17	0.17	1.44	1.43	1.24	1.22	0.641	0.641	0.29	0.30
SEm±	0.062	0.068	0.034	0.036	0.039	0.040	0.029	0.030	0.004	0.005	0.003	0.002
LSD (P=0.05)	0.018	0.020	0.009	0.014	0.009	0.012	0.006	0.009	0.002	0.001	0.008	0.008
FYM Levels												
F_0	1.72	1.72	0.24	0.25	1.52	1.51	1.36	1.37	0.701	0.693	0.26	0.26
F_1	1.74	1.75	0.26	0.27	1.55	1.53	1.41	1.42	0.703	0.703	0.25	0.25
F_2	1.79	1.79	0.29	0.30	1.58	1.57	1.48	1.48	0.705	0.706	0.24	0.24
F_3	1.87	1.87	0.30	0.31	1.64	1.65	1.56	1.56	0.707	0.606	0.23	0.23
SEm±	0.005	0.006	0.002	0.003	0.042	0.040	0.003	0.003	0.004	0.004	0.003	0.002
LSD (P=0.05)	0.015	0.018	0.006	0.009	0.012	0.012	0.009	0.009	0.012	0.001	0.008	0.007

Table 4. Uptake (mg/pot) of N, P, K, Ca, Mg and Na by oat as influenced by RSC and FYM levels

Treatment	N (mg/pot) Mean		P (mg/pot) Mean		K (mg/pot) Mean		Ca (mg/pot) Mean		Mg (mg/pot) Mean		Na (mg/pot) Mean	
RSC Levels	2003	2004	2003	2004	2003	2004	2003	2004	2003	2004	2003	2004
S_1	68.00	75.90	9.20	9.70	58.50	65.90	46.30	48.28	27.30	30.27	10.04	11.26
S_2	65.00	59.60	7.50	8.20	50.80	52.60	44.40	46.28	23.40	24.45	9.36	10.02
S_3	45.30	47.50	6.90	7.10	47.00	48.40	40.40	41.71	21.50	22.11	8.84	9.37
S_4	33.90	36.10	5.40	5.30	40.90	42.90	35.00	36.46	18.70	19.61	8.08	8.76
S_5	90.90	21.60	3.20	3.30	26.20	28.10	22.20	23.83	11.80	12.55	5.36	5.89
SEm ±	0.045	0.039	0.030	0.056	0.248	0.327	0.255	0.395	0.261	0.184	0.035	0.025
LSD (p= 0.05)	0.112	0.115	0.085	0.157	0.701	0.923	0.715	1.120	0.748	0.531	0.010	0.075
FYM Levels												
F_0	63.30	75.30	8.90	10.60	55.60	66.40	48.90	60.08	25.70	30.67	9.42	11.30
F_1	83.60	85.70	12.50	13.00	74.10	75.20	66.00	68.53	33.60	34.41	11.82	12.30
F_2	98.30	101.10	15.30	16.10	86.50	56.60	78.30	80.69	38.60	39.84	9.83	13.63
F_3	116.10	125.50	18.20	20.30	102.10	69.90	92.10	101.44	43.90	45.35	14.52	15.47
SEm±	0.042	0.038	0.539	0.317	0.170	0.245	0.294	0.255	0.368	0.380	0.030	0.003
LSD (P=0.05)	0.112	0.112	1.536	0.898	0.470	0.701	0.831	0.718	1.052	1.091	0.008	0.008

The sodium content at each cutting increased significantly with increasing RSC levels of irrigation water. Data indicated that sodium content of o at S_2 level was at par with S_3 pooled data of *rabi* 2004. The sodium content significantly at S3, S4 level of RSC in comparison to control pooled data of *rabi* 2003.

Uptake of nutrients

Each increment in RSC value decreased significantly the nitrogen uptake by oat as compared to control and rest of the RSC values. Highest reduction in nitrogen uptake was observed in S_5 treatment during both years of experimentation, the results are in conformity with the findings of Singh *et al,* (2005). Phosphorus uptake by oat as compared to control during *rabi* 2003-04 also decreased significantly. Similar effect of RSC of irrigation water on phosphorus uptake was also reported by earlier workers in cotton in accordance Paliwal *et al,* (1978), Singh *et al,* (2005). The trend of calcium and potassium uptake by oat was also similar to that of nitrogen. The maximum adverse effect was noted with RSC (S_5) in comparison to other RSC levels and maximum uptake was observed significantly with F_3 level of FYM. The Magnesium uptake decreased significantly with increasing RSC levels of irrigation water in comparison to preceding lower levels of RSC during *rabi* 2003-04 (Table 4). The maximum significant reduction in magnesium uptake was noted at S_5 level of RSC as compared to control throughout the experimentation. Similar adverse effect of RSC was noted by Singh *et al,* (2005). From the results it may be inferred that RSC levels of irrigation water significantly decreased the sodium uptake of each cutting of oat during both the years. It seems that less sodium content accumulation in tissues and depressed dry matter production of oat due to sodicity of water resulted sodium uptake in this investigation. Paliwal *et al,* (1978), Singh *et al,* (2005) have also reported that uptake of sodium was decreased with increased bicarbonate concentration.

CONCLUSION

From this study it can be concluded that the green foliage of oat was significantly reduced at RSC level of 20meq/l. However, application of FYM minimized the sodicity and improved the yield attributes of oat. It can be further concluded that application of FYM 15t/ha significantly suppressed the sodicity up to 10 m /l.

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Influence of tillage, crop establishment and weed control methods on the productivity of wheat

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ABSTRACT

During 2004-05 and 2005-06, field experiments were carried out to study the influence of tillage operations, crop establishment and weed control methods on the productivity of wheat. The result indicated that tillage operation methods - convention line sowing and furrow irrigated raised bed systems (FIRBS) significantly reduced total weed dry weight (gm^{-2}) at different crop growth stages ,grain yield, biomass yield, gross return (Rs/ha) and net return. Application of metribuzin was found to be more efficient in reducing weed dry weight in comparison with sulfosulfuron with FIRBS and conventional line sowing.

Key words : Weed control efficiency, FIRBS, wheat, metribuzin, sulfosulfuron, weed dry weight, tillage operations

During the past few years, stagnation or decline in the productivity of wheat crop has raised doubts on the sustainability. The resource degradation is proceeding at an alarming rate in the western plain area of U.P. for the wheat productivity which includes deterioration of soil physical properties due to widely adopted practices of tillage in wheat cultivation build up of weed population, decline in factor productivity of input, receding water table in certain area etc. With the availability of better farm machines and herbicides together with economic pressure to reduce the cost of production there is need to develop alternate tillage practices by reducing tillage operation and better crop establishment for wheat crop in conjunction with the use of herbicide for effective control of weeds. Keeping the above facts in view. The present study was under taken to study the influence of various tillage operations with the high potency herbicide is recommended how-a-day replacing the use of isoproturen.

MATERIALS AND METHODS

Field experiments were conducted from 2004-2005 to 2005-06 at Instructional Farm of Amar Singh (PG) College, Lakhaoti Bulandshahr (28°4' N latitude, 77°11' E longitude and 207.1m above msL). The soil was sandy loam having 64% sand, 18% silt and 18% clay, 0.4% organic C, 180 kg/ha, 10 Kg/ha available P and 153 Kg/ha available K and had a pH of 7.6 at the start of the experiment. The experiments were laid out in a split-plot design with 4 replications. The treatments consist of 6 tillage options -Strip Till Drill (STD), Zero Tillage (ZT), Surface Seeding (SS), Reduce Tillage (RT), Conventional Line Sowing (CLS) and Furrow Irrigated Raised Bed planting System (FIRBS) in main plots and 3 herbicide treatments -metribuzin @ 250g/ha, sulfosulfuron @ 33 g/ha and weedy check in sub plots. The treatments were continued throughout the study in the same plots. The main plot size was 6.4 m × 6.0 m and sub-plot size was 1.8m × 6 m size. Herbicide doses mixed in 250 litres of water and applied at 30 day after sowing (DAS). Weedy plot remained infested with native population throughout the cropping season. Wheat crop was sown directly without any pre-tillage with the help of strip-till-drill and using a specially designed Pantnagar Zero-till-ferti seed-drill. In surface seeding-seed was broad casted after the harvesting of previous crop. In reduced tillage plots, the land was prepared by 3 harrowing and 2 plankings, where as in conventional line sowing and FIRBS, the land was prepared by 6 harrowing and 2 plankings. The tillage requirement for FIRBS was similar to conventional system and sowing was done on raised bed with specially designed FIRBS seed drill.

Wheat 'PBW-343' was sown in the third week of November every year of the experimentation. The crop received 75 kg N/ha as urea, 60 Kg P_2O_5/ha through DAP and 40 kg K_2O/ha through muriate of potash at sowing and 75 kg N/ha as urea at 40 days after sowing. The crop was harvested in third week of April each year of the experimentation. Economics were calculated by considering the prevailing the sale price of wheat and the cost of cultivation.

RESULTS AND DISCUSSION

Weed dry weight

Weed dry matter increased with the advancement of the crop growth in both years. There was significantly influenced of tillage options and herbicide application on total weed dry weight. It was significantly higher under surface seeding than other tillage options at all the growth stages (Table 1). FIRBS gave significantly lower total weed dry weight than other tillage options at 30,45 and 60 days after sowing except CLS at 60 days, but at 90 and 120 days produced significantly lower weed dry weight than other tillage options. Herbicide treated plot produced significantly lower weed dry matter than weedy check at all the stages. During first year, metribuzin observed to be more efficient than sulfosulfuron while reverse was true in second year.

Herbicide application when combined with the tillage options reduced the total weed dry weight significantly whereas in weedy check, the total dry weight of weeds were more than any other treatment combinations, irrespective of stages of crop and year. FIRBS, RT and CLS reduced effectively weed dry weight than STD, ZT and SS with the application of herbicide. The crop grown under FIRBS & CLS proved reasonably good control of *Phalaris minor* (Chauhan *et al.* 1998). The problem of *Phalaris minor* was comparatively less as the weed seed lying on the top of the bed dried out quickly in FIRBS method in case of deeper soil, compaction of soil inhibiting the germination of weeds. Verma & Srivastava (1989) also found optimal tilled plot had 21-28 percent more weeds / unit than zero tillage plots.

Yield

Influence of various tillage options and herbicides was significant on grain yield, biomass yield while it was non-significant on harvest index during both the years (Table 2). Higher grain and biomass yield was observed under tilled plots than that under untilled plots. The CLS, RT and FIRBS systems produced consistently higher grain and biomass yield as compared to other tillage option during both the years. Tillage options failed to influence the harvest index, but herbicide application alone had significant influence on the harvest index during both the years. Grain and biomass yield reduction in SS, ZT and STD was mainly due to lower crop emergence, growth and higher weed infestation, which could not be controlled even with herbicide application. Conventional tillage produced 16-25 percent higher grain yield of wheat than zero tillage Catizone *et al.* (1990).

Influence of herbicide application was found to be significant on grain and biomass yield due to reduction in total weed dry weight, less crop weed competition for space, light, moisture and nutrients resulted in better crop establishment and it also reduces tiller mortality and ultimately increased grain and biomass yield. Dixit and Bhan (1996 & 1997) also reported that application of herbicide decreased the weed population and resulted in higher grain yield of wheat crop.

Economic studies

The cost of cultivation was lower under ZT and weedy check while it was found almost equal under CLS and FIRBS methods (Table 3). The herbicide application increased the cost of cultivation with tillage options and found more with sulfosulfuron application. Higher gross return of crop was under RT, CLS and FIRBS in

Table 1. Total weed dry weight (gm^{-2}) as influenced by tillage options and herbicide application at different growth stages

Treatment	Crop Stages (Days after sowing)									
	2004-05					2005-06				
	30	45	60	90	120	30	45	60	90	120
Tillage and crop establishment										
STD	2.62	3.62	4.04	3.59	4.48	2.72	3.65	4.04	5.14	5.87
	(13.0)	(39.9)	(67.8)	(82.9)	(180.0)	(14.4)	(42.0)	(65.8)	(210.0)	(449.0)
ZT	2.65	3.75	4.21	4.09	4.86	2.86	3.72	3.99	5.39	5.99
	(13.5)	(47.1)	(75.9)	(85.1)	(276.0)	(16.8)	(44.1)	(61.9)	(246.0)	(457.0)
SS	3.00	4.09	4.36	4.49	5.01	3.00	3.75	4.09	5.55	6.07
	(19.4)	(67.8)	(92.5)	(117.7)	(326.0)	(19.1)	(48.6)	(70.8)	(284.0)	(530.0)
RT	2.69	3.76	3.61	3.51	4.42	2.84	3.62	3.91	5.03	5.47
	(14.2)	(51.2)	(61.2)	(69.2)	(243.0)	(16.3)	(44.0)	(65.7)	(219.0)	(416.0)
CLS	2.56	3.50	2.87	2.83	3.58	2.88	3.58	3.84	5.17	5.61
	(12.3)	(34.3)	(49.6)	(58.2)	(236.0)	(17.0)	(45.2)	(67.6)	(234.0)	(460.0)
FIRBS	2.22	3.21	2.76	2.86	3.85	2.80	3.63	3.76	5.18	5.56
	(8.9)	(26.1)	(44.8)	(47.7)	(220.0)	(15.7)	(46.8)	(64.0)	(230.0)	(459.0)
SEm ±	0.057	0.048	0.185	0.248	0.292	0.51	0.031	0.23	0.036	0.62
CD	0.172**	0.143**	0.558**	0.750**	0.881**	0.154*	0.09*	0.07*	0.12*	0.19*
Herbicide application										
Metribuzine	2.64	3.27	2.97	2.58	3.16	2.87	3.28	3.47	4.82	5.24
	(13.9)	(29.4)	(29.9)	(24.7)	(45.0)	(17.0)	(26.0)	(32.1)	(127.0)	(201.0)
Sulfosulfuron	2.60	3.33	3.05	2.92	3.49	2.83	3.27	3.44	4.79	5.15
	(13.1)	(27.9)	(30.8)	(23.2)	(41.2)	(16.1)	(25.4)	(30.9)	(126.0)	(194.0)
Weedy check	2.64	4.26	4.89	5.18	6.45	2.85	4.43	4.90	6.10	6.89
	(13.6)	(75.9)	(135.2)	(182.6)	(655.0)	(16.6)	(84.0)	(134.9)	(458.0)	(990.0)
SEm ±	0.04	0.32	0.08	0.12	0.15	0.03	0.02	0.02	0.02	0.05
CD	NS	0.92**	0.25**	0.34**	0.44**	NS	0.06**	0.05**	0.06**	0.13**

( )- Original values in parenthesis, *= Significant at 5% level, **= Significant at 1% level

comparison to STD, ZT and SS during both the years. Net return of crop found to be greater under RT followed by FIRBS and CLS. Incase of herbicide application net return was greater with the application of metribuzin over applications of sulfosulfuron in both the years.

Maximum return per rupees invested (B:C ratio) was obtained with STD (2.66:1) in 2004-05 and with RT (3.96:1) in 2005-06. Due to application of herbicide B : C ratio was higher with metribuzin application during both the years.

The results thus indicate that under tilled condition with application of herbicide RT, CLS and FIRBS consistently produced higher grain yield, biomass yield, gross return and net return than STD, ZT and SS. Reduced tillage (RT) followed by FIRBS method with metribuzin application might be an economic viable and good alternative practice in wheat cultivation for reducing the cost of production and increasing the net income.

Table 2. Grain yield biomass yield and harvest index of wheat as influenced by tillage options and herbicide application

Treatment	Crop Stages (Days after sowing)					
	2004-05			2005-06		
	Grain Yield (t/ha)	Biomass Yield (t/ha)	Harvest Index (%)	Grain Yield (t/ha)	Biomass Yield (t/ha)	Harvest index (%)
Tillage and crop establishment						
STD	3.90	9.60	0.41	4.88	12.61	0.38
ZT	3.40	8.21	0.42	4.30	11.45	0.37
SS	2.33	5.45	0.43	4.87	13.21	0.37
RT	4.38	10.78	0.41	5.60	14.81	0.39
CLS	4.11	10.20	0.40	5.61	15.01	0.37
FIRBS	3.72	9.11	0.41	5.36	13.95	0.39
SEm ±	0.125	0.21	0.01	0.13	0.42	0.01
CD	0.38**	0.64**	NS	0.41**	1.27*	NS
Herbicide application						
Metribuzine	4.01	9.74	0.42	5.33	14.02	0.38
Sulfosulfuron	4.03	9.76	0.42	5.46	13.86	0.39
Weedy check	3.13	7.83	0.40	4.56	12.63	0.36
SEm ±	0.80	0.16	0.01	0.06	0.22	0.00
CD	0.22**	0.45**	0.02*	0.17**	0.62**	0.01**

*= Significant at 5% level, **= Significant at 1% level

Table 3. Economics of wheat under different tillage options and herbicide application

Treatment	Cost of Cultivation (Rs/ha)		Gross Return (Rs/ha)		Net Return (Rs/ha)		B : C Ratio	
	2004-05	2005-06	2004-05	2005-06	2004-05	2005-06	2004-05	2005-06
Tillage and crop establishment								
STD	9003.9	9706.4	33014	46420	24010.1	36713	2.66	3.78
ZT	8939.5	9642.5	28545	41430	19605.5	31787	2.19	3.29
SS	9040.4	9743.4	19562	47549	10521.6	37805	2.06	3.88
RT	10246.5	10,949.5	37077	54325	26830.5	43375	2.61	3.96
CLS	11210.4	11913.4	34844	54369	23633.6	42455	2.10	3.56
FIRBS	11210.4	11913.4	36709	51238	25498.6	39324	2.27	3.30
Herbicide application								
Metribuzine	10687.7	11391.4	33709	51205	23021.3	39814	2.15	3.49
Sulfosulfuron	11685.4	12253.0	33819	51383	22133.6	39129	1.89	3.19
Weedy check	9941.4	10644.2	26617	45078	16675.6	34433	1.67	3.23

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Production potential and economics of different cropping systems at farmer's field in different blocks of Tikamgarh district of Madhya Pradesh

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ABSTRACT

Field experiment was conducted during two consecutive years (2007-08 and 2008-09) to study the productivity and economics of different cropping systems at farmer's field in 5 blocks of Tikamgarh district of Madhya Pradesh. The pooled data revealed that the total productivity in terms of seed yield (45.0 q/ha) as well as wheat equivalent yield (54.1 q/ha) was recorded the highest in soybean-wheat system. Similarly, production efficiency (19.3 kg/ha/day) and net monetary return (Rs. 36882/ha) was also recorded the highest in soybean-wheat system. However, net monetary return per day was recorded the maximum in blackgram-coriander (Rs.160/ha/day) and closely followed by soybean-wheat (Rs. 158/ha/day) system. Soybean-wheat system gave an advantage of net return of Rs. 10467, Rs. 8007 and Rs. 1310/ha over sesame-wheat, blackgram-mustard and blackgram-coriander system, respectively. Similarly, increase in net monetary return from blackgram-coriander over sesame-wheat was Rs. 9157/ha and over blackgrammustard was Rs.6697/ha. Net return per rupee invested (B:C) was recorded highest in blackgram-coriander (1.92) and the lowest in sesame-wheat (1.07) system. It was evident from the results that soybean-wheat system exhibited superiority over other cropping systems in Tikamgarh district. Similarly, growing of coriander after blackgram was more remunerative than mustard. Blackgram-coriander system was also profitable over sesame-wheat system.

Key words : Benefit cost ratio, cropping systems, coriander, net monetary return, soybean, mustard, wheat equivalent yield

A number of cropping systems are adopted by the farmers of Madhya Pradesh and the major cropping sequences followed are soybean-wheat, soybean-chickpea and pigeon pea/corn as intercrops in soybean (Yadav and Subba Rao, 2001). However, soybean-wheat is the dominant cropping system in Tikamgarh district of Madhya Pradesh (Tomar *et al.*, 1996). A suitable cropping system is essential for increased productivity per unit area and per unit time. Cropping systems of a region are decided by and large, by a number of soil and climatic parameters which determine overall agro-ecological setting for nourishment and appropriateness of a crop or set of crops for cultivation. Nevertheless, at farmers' level, potential productivity and monetary benefits act as guiding principles while opting for a particular crop/cropping system. The production potential and economics vary with cropping systems and availability of resources (Kumar and Singh, 2005). The net return per unit area and per unit time can be further increased in this region by adopting other feasible and profitable cropping systems. Blackgram, mustard, coriander and sesame (til) are also immensely suitable for cultivation in this area. Inclusion of these crops in the sequences can change the economics of the sequence cropping (Umrani *et al.*, 1993). So comparing the suitability of the alternative crops and raising them in appropriate sequences can lead to the development of such cropping systems which provides the farmers maximum production and net return as well as reasonable high input use efficiency.

A study was therefore, initiated to assess the production potential and economics of different cropping systems at farmer's field in Tikamgarh district of Madhya Pradesh during the year 2007-08 and 2008-09.

MATERIALS AND METHODS

The field experiment was conducted during two consecutive years (2007-08 and 2008-09) under ECF scheme of AICRP on cropping system at farmer's field in 5 blocks viz., Tikamgarh, Prithvipur, Niwari, Jatara and Baldeogarh of Tikamgarh district of Madhya Pradesh. Tikamgarh district is situated between 24°.26 to 25°.40 latitude and 78°.26 to 79°.56 longitudes with altitude of 426.7 metres above the mean sea level. About 60 % of soil falls under black and rest 40 % is sandy loam to red soil in the district. Climate of district is moderate, generally dry except rainy season. The district receives an average annual rainfall of 1001 mm in 32 rainy days. Average temperature in summer varies from 23 °C to 44 °C and average temperature in winter season varies from 4.5 to 25.4 °C.

In each block, 5 villages were selected and in each village, one farmer was selected for conducting field trial. In this way, field trial was conducted at 25 locations each in kharif and *rabi* seasons keeping a plot size of 10x15 m². For statistical analysis purpose, each block was considered as one replication and only seed yield data was analyzed as per randomized block design. The treatments comprised 4 different double cropping sequences *viz.*, T_1: soybean-wheat, T_2: blackgram-mustard, T_3: sesame (til)-wheat and T_4: blackgram-coriander. The varieties of crops are soybean, blackgram, sesame, coriander, mustard and wheat were JS-9305, PU 35, JS 8, JD-1, Rohini and GW 273, respectively. Crops during *kharif* season were raised as rainy crops and *rabi* crops were given irrigations as per the recommendations. As per technical programme of AICRP, all *kharif* and rabi crops were grown under rainfed and irrigated conditions, respectively. All *kharif* crops were sown with the onset of monsoon as rainfed and *rabi* crops were sown with pre-sowing irrigations for better germination and optimum plant population of the crops. Fertilizers were applied as per the recommendation to respective crops (Table 1). All other agronomic operations and plant protection measures were followed as per the recommendations.

Table 1. Fertilizer management in *kharif* and *rabi* crops

Crops	N (kg/ha)	P_2O_5 (kg/ha)	K_2O (kg/ha)
Soybean	20	80	20
Sesame	40	30	20
Blackgram	20	50	20
Wheat	120	60	40
Mustard	80	40	20
Coriander	60	30	20

Yield data were transformed into economic data by taking into account the prevailing market price during the study. The market price (Rs./q) during 2007-08 and 2008-09 for soybean 2000 and 2000, for wheat 1200 and 1200, for blackgram 2500 and 2500, for mustard 2000 and 2500, for sesame (til) 3000 and 3200 and for coriander 4000

Table 2. Rainfall (mm) and rainy days in different blocks of Tikamgarh district

Blocks	2007-08		2008-09	
	Rainfall (mm)	Rainy days	Rainfall (mm)	Rainy days
Tikamgarh	274	25	1401	47
Prithvipur	589	36	1108	58
Niwari	357	30	1219	49
Jatara	413	25	1225	33
Baldeograh	225	20	902	33

and 4000, respectively. To compare productivity of different cropping systems, wheat grain yield equivalents (WEY, q/ha) was computed by converting the grain yield of other crops into wheat grain yield on the basis of selling price during the respective years. The net return (Rs./ha) and benefit cost ratio (B:C) were calculated on the mean basis to judge the best cropping sequence to be adopted by farmers for sustainable crop production. The rainfall data prevailed during two years in 5 blocks is given in Table 2.

RESULTS AND DISCUSSION

Influence of weather condition

A well distributed higher amount of rainfall in all 5 blocks of Tikamgarh district during the year 2008-09 resulted into higher seed yield of all crops except sesame in different cropping sequences than 2007-08 (Table 2). The higher seed yield during 2008-09 also reflected into higher WEY (q/ha) and NMR (Rs./ha). However, excess vegetative growth of sesame due to high rainfall during 2008-09 resulted into poor fruit setting and reflected into low seed yield (Table 3).

Cropping system productivity

Among the *kharif* crops, soybean recorded significantly higher grain yield as compared to other crops during both the years of study. Similarly, among *rabi* crops, wheat exhibited significantly higher grain yield followed by mustard and coriander (Table 3). The pooled data revealed that among different cropping systems, the highest total productivity in terms of seed yield was recorded from soybean-wheat (45.0 q/ha) followed by sesame-wheat (36.0 q/ha), blackgram-mustard (20.3 q/ha) and the lowest was from blackgram-coriander (15.4 q/ha) system (Table 3). Tomar *et al.* (1996) also reported the highest total productivity of soybean-wheat system at Tikamgarh district. Similarly, total productivity in terms of wheat equivalent yield (WEY), soybean-wheat system also recorded the maximum WEY (54.1 q/ha) followed by blackgram-coriander (45.1 q/ha), sesame-wheat (42.7 q/ha) and was the minimum in blackgram-mustard (39.2 q/ha). The higher WEY of soybean-wheat system was owing to the fact that these crops have high yield potential than other crops in different cropping systems. Production efficiency (per day productivity) among different cropping systems was also observed the highest in soybean-wheat (19.3 kg/ha/day) and the lowest in blackgram-coriander (6.91 kg/ha/day) system (Table 4).

Cropping system economics

The net return (Rs./ha) of different cropping systems was higher in 2008-09 than 2007-08 probably due to higher grain yield of crops in 2008-09. The higher grain yield of crops in 2008-09 was due to better rainfall amount and its well distribution resulted into vigour plant growth. The highest net monetary return (NMR) of Rs. 36882/ha was recorded from soybean-wheat system and the lowest NMR of Rs. 26415/ha from sesame-wheat system (Table 4). Higher NMR from soybean-wheat system among different cropping systems was also reported by

Table 3. Seed yield and wheat equivalent yield (WEY) of different cropping systems (q/ha)

Treatments	Seed/Grain yield (q/ha)							Mean WEY (q/ha)
	2007-08		2008-09		Mean			
	Soybean	Wheat	Soybean	Wheat	Soybean	Wheat	Total	
Soybean-wheat	12.6	27.9	14.5	34.9	13.6	31.4	45.0	54.1
Blackgram-mustard	4.58	15.5	5.27	15.3	4.93	15.4	20.3	39.2
Sesame-wheat	4.50	28.2	4.04	35.1	4.27	31.7	36.0	42.7
Blackgram-coriander	4.55	9.55	5.17	11.4	4.86	10.5	15.4	45.1
S.Em ±	0.11	0.81	0.54	0.97	0.33	0.89	0.85	
C.D. (P=0.05)	0.35	2.49	1.67	2.95	1.01	2.72	2.67	

Table 4. Productivity, net return and benefit cost ratio (B:C) from different cropping systems

Treatments	Total duration of system (days)	Production efficiency of system (kg./ha/day)	Net monetary return (Rs./ha)			Net monetary return (Rs./ha/day)	Benefit cost ratio (B:C)	Increase in net return over (Rs./ha)		
			2007-08	2008-09	Mean			Black gram-mustard	Sesame-wheat	Black gram-coriander
Soybean-wheat	233	19.3	32035	41728	36882	158	1.32	8007	10467	1310
Blackgram-mustard	220	9.23	24561	33189	28875	131	1.60	-	2460	-
Sesame-wheat	231	15.6	22965	29864	26415	114	1.07	-	-	-
Blackgram- coriander	223	6.91	31094	40049	35572	160	1.92	6697	9157	-

Singh and Lal (1994) at Pantnagar, Uttrakhand. However, NMR per day was recorded the highest in blackgram-coriander (Rs.160/ha/day) system closely followed by soybean-wheat (Rs. 58/ha/day), blackgram-mustard (Rs. 131/ha/day) and was the lowest in sesame-wheat (Rs. 114/ha/day) system. Soybean-wheat system gave an advantage of NMR of Rs. 10467/ha over sesame-wheat, Rs. 8007/ha over blackgram-mustard and Rs. 1310/ha over blackgram-coriander system. Similarly, increase in NMR from blackgram-coriander over sesame-wheat was Rs. 9157/ha and over blackgram-mustard was Rs.6697/ha. Mean net return per rupee invested (B: C) was also recorded highest in blackgram-coriander (1.92) and was the lowest in sesame-wheat (1.07) system (Table 4).

Thus it was evident from the results that soybean-wheat system exhibited superiority over other cropping systems in Tikamgarh district of Madhya Pradesh. Similarly, growing of coriander crop after blackgram is more remunerative than growing mustard crop. Blackgram-coriander system was also profitable over sesame-wheat system in Tikamgarh district.

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Effect of phosphorus, sulphur and phosphate solubilizing bacteria on productivity and nutrient uptake of chickpea

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ABSTRACT

A field experiment was carried out during *rabi* 2007-08 and 2008-09 at Bulandshahr in Uttar Pradesh to study the effect of levels of phosphorus, sulphur and phosphate solubilizing bacteria (PSB) on the productivity and nutrient uptake of chickpea. Application of 60 kg P_2O_5 and 80 kg S/ha with PBS inoculation significantly improved growth and yield attributes and seed yield of chickpea over their lower levels. Uptake of N, P, K and S too were increased with the application of phosphorus (up to 60 kg P_2O_5/ha) and sulphur (up to 80 kg S/ha) and PSB inoculation.

Key words : Chickpea, nutrient uptake, phosphorus, PSB, sulphur, yield

Chickpea (*Cicer arietinum* L.) is the leading pulse crop and rich source of protein (20%) in India. It occupied 6.93 m ha area with a production of 5.60 million tonnes at an average yields of 808 kg/ha during 2005-06 (GOI, 2007). It is grown in *rabi* both irrigated and rainfed conditions. Chickpea responds positively to application of phosphorus. Since phosphorus is a very costly input, its judicious use will be very important to reduce the cost of cultivation and increase the returns from the investment made on this costly input. Further, phosphorus is known to be fixed in the soil and often becomes unavailable to the crop. The availability of phosphorus to the crop can be augmented by providing appropriate strains of microbes which are known to solubilize the fixed phosphorus and mobilize the deeply placed phosphorus to root zone by their activity. The seed treatment with phosphate solubilizing bacteria (PSB) like *Pseudomonas striata, Bacillus megaterium* etc. will be helpful in increasing the availability of fixed phosphorus in the soil. These cultures besides augmenting the availability of native phosphorus in the soil also help in enhancing the use-efficiency of the applied phosphorus. Sulphur is another nutrient which is needed in a large quantity. It is involved in the synthesis of amino acids, the building blocks of protein. As chickpea is rich in protein, its requirement is also relatively higher. Use of high analysis fertilizers devoid of sulphur content over the years has caused decline in the availability of the sulphur in soil leading to sulphur deficiency in many areas. Keeping all these points in view a field experiment was carried-out to study the effect of phosphorus, phosphate solubilizing bacteria (PSB) and sulphur on growth, yield and nutrient uptake of chickpea.

MATERIALS AND METHODS

A field experiment at the Agronomy Research Farm, Amar Singh College, Lakhaoti, and Bulandshahr (U.P.) during *rabi* 2007-08 and 2008-09. Soil of the experimental field was well drained sandy-loam in texture and medium in fertility with slightly alkaline in reaction. It was low in organic carbon and medium in phosphorous and sulphur content. The experiment was laid out in a factorial RBD replicated thrice. The treatments consisted of three phosphorus levels in the form of DAP *viz.* 0, 30 and 60 kg P_2O_5/ha; two bio-fertilizer levels *viz.* control and PSB inoculation (*Pseudomonas striata*), and three levels of sulphur in the form of gypsum viz. 0, 40 and 80 kg S/ha to timely sown chickpea (var. 'Pusa 256'). Chickpea was sown in the third week of October and harvested during end of March. Observations on growth and yield attributes and yield, nutrient content and uptake were recorded and analyzed as per the standard procedures.

RESULTS AND DISCUSSION

Growth attributes of chickpea

Growth parameters, viz. plant height, dry matter accumulation, number of branches/plant were significantly influenced by the levels of phosphorus. Application of 60 kg P_2O_5/ha recorded the highest values of all these parameters. It was closely followed 30 kg P_2O_5/ha and least was observed with no phosphorus appliction (Table 1). The phosphate solubilizing bacteria (PSB) *viz.* PSB inoculation too increased all these growth parameters significantly as compared to control. Among the levels of sulphur, 80 kg S/ha recorded the highest values of plant height, dry matter accumulation, number of branches at harvest. It was closely followed by 40 kg S/ha and the least values were observed with 0 kg S/ha. The nodulation too was significantly affected by these treatments. Application of 60 kg P_2O_5/ha, phosphate solubilizing bacteria (PSB) inoculation, 80 kg S/ha showed significant increase in number of nodules, nodule biomass both at 45 DAS and at 75 DAS in both the years of experimentation. The days to 50% flowering was too affected by these treatments, where in the highest levels of phosphorus i.e. 60 kg P_2O_5/ha, phosphate solubilizing bacteria (PSB) inoculation and 80 kg S/ha showed longer period as compared to their lower levels. This may be attributed to continued availability of phosphorus due to readily available form of phosphorus from the phosphorus treatments, which is said to be one of the main nutrients for the performance of chickpea. The phosphate solubilizing bacteria

Table 1. Growth attributes, yield attributes and yield of chickpea as influenced by phosphorus, PSB and sulphur (Mean of 2 years)

Treatment	Plant height (cm)	Dry matter accumulation (g/plant)	No. of branches/plant	Days to 50% flowering	Pods/plant	100 seed weight (g)	Seeds yield (kg/ha)	Harvest index (%)
Phosphorus (kg P_2O_5/ha)								
0	52.2	15.1	5.8	73.8	16.5	23.0	1408.5	25.9
30	53.3	15.4	5.9	75.6	22.4	25.8	1624.5	28.2
60	56.9	16.5	6.3	76.4	26.3	27.4	1765.5	31.1
SEM+	0.96	0.28	0.11	0.42	0.32	0.26	27.0	0.27
C.D. (P=0.05)	2.74	0.8	0.33	1.20	0.92	0.73	78.0	0.79
Phosphate Solubilizing bacteria								
Control	52.4	15.2	5.8	74.0	20.9	24.7	1556.0	27.8
Inoculatrd	55.8	16.2	6.2	76.2	22.7	26.1	1643.0	29.0
SEM+	0.8	0.2	0.1	0.34	0.3	0.2	22.5	0.2
C.D. (P=0.05)	2.24	0.65	0.27	1.10	0.75	0.6	63.5	0.64
Sulphur (kg/ha)								
0	50.5	14.64	5.63	74.1	19.6	24.3	1495.5	27.8
40	53.6	15.6	6.0	75.3	22.7	25.6	1614.0	28.6
80	58.2	16.9	6.4	76.4	23.0	26.3	1688.5	28.8
SEM+	0.96	0.28	0.11	0.42	0.32	0.26	27.0	0.27
CD (P=0.05)	2.74	0.80	0.33	1.35	0.92	0.73	78.0	0.79

(PSB) inoculation further helped to achieve easy availability of phosphorus. Shivakumar *et al.* (2004) also observed increased phosphorus availability and higher productivity of chickpea due to PSB inoculation. The sulphur being an important component of many physiological processes was also responsible for the positive impact on many of these growth parameters.

Yield attributes and yield of chickpea

The yield parameters viz. number of pods/ plant, seeds/pod, pod yield per plant, 100 seed weight were too significantly affected by the levels of phosphorus, phosphate solubilizing bacteria (PSB) inoculation and sulphur (Table 1). The application of 60 kg P_2O_5/ha , recorded the highest values of all these yield parameters. The next best was 30 kg P_2O_5/ha and the least was with control. The phosphate solubilizing bacteria (PSB) inoculation recorded significantly higher growth parameters vis-à-vis the control. Among the sulphur levels, application of 80 kg S/ha recorded the highest values of yield parameters. All this might be attributed to improved growth parameters and continued positive influence of the treatments on the yield parameters. Reddy and Ahlawat (1998) and Chaudhary and Goswami (2006) also recorded increased yield of chickpea due to application of sulphur and phosphorus.

The seed yield and harvest index were significantly increased by the application of 60 kg P_2O_5/ha, phosphate solubilizing bacteria (PSB) inoculation and 80 kg S/ha. They recorded significantly higher yield and harvest index as compared to 30 kg P_2O_5/ha and control. This may be attributed to greater availability of phosphorus due to these treatments and better growth and yield attributes. Similar results were also observed by Jat and Ahlawat, (2004).

Nutrient uptake by chickpea

The content and uptake of N, P and S (Table 2) were also affected by the treatments. The application of 60 kg P_2O_5/ha, 80 kgS/ha and seed inoculation with PSB recorded the highest content and uptake of these nutrients. However, the K content and uptake were not influenced by the treatments. This may be attributed to

Table 2. Content (%) and uptake (kg/ha) of nitrogen (N), phosphorus (P), potassium (K) and sulphur(S) in chickpea seeds as influenced by phosphorus, PSB and sulphur (Mean of 2 years)

Treatment	Content				Uptake			
	N	P	P	S	N	P	P	S
Phosphorus (kg P_2O_5 /ha)								
0	2.47	0.32	0.93	0.28	34.9	4.5	13.1	4.0
30	2.67	0.33	0.94	0.28	43.5	5.4	15.3	4.6
60	2.82	0.34	0.95	0.28	50.0	6.0	16.8	5.0
SEM+	0.034	0.003	0.014	0.002	1.05	0.09	0.41	0.09
CD (P=0.05)	0.096	0.007	NS	NS	3.01	0.26	1.17	0.26
Phosphate solubilizing bacteria								
Control	2.59	0.33	0.94	0.28	40.6	5.1	14.6	4.4
Inoculation	2.72	0.34	0.94	0.28	44.9	5.5	15.6	4.7
SEM+	0.028	0.002	0.012	0.002	0.86	0.07	0.34	0.08
CD (P=0.05)	0.079	0.006	NS	NS	2.46	0.21	NS	0.22
Sulphur (kg/ha)								
0	2.62	0.33	0.92	0.26	39.4	4.9	13.8	3.9
40	2.64	0.33	0.94	0.29	42.9	5.4	15.2	4.7
80	2.71	0.33	0.96	0.30	46.0	5.7	16.2	5.0
SEM+	0.034	0.003	0.014	0.002	1.05	0.09	0.41	0.09
CD (P=0.05)	NS	0.005	NS	0.007	3.01	0.26	1.17	0.26

higher availability of phosphorus and sulphur and their complementary effect on the growth of and development. Since the uptake is directly related to content and biomass, the increased biomass recorded higher uptake too. The results are in conformity with the findings of Jain and Singh (2003) and Jain *et al.* (2006).

On the basis of this 2 years study it may be concluded that application 60 kg P_2O_5/ha and 80 kg S/ha alongwith phosphate solubilizing bacteria (PSB) is highly beneficial for chickpea in the medium fertile alluvial sandy loam soils of northern plains zone of India.

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Effect of integrated nutrient management on nutrient uptake and economics of okra [*Abelmoschus esculentus* (L.) Monech] and its residual effect on radish (*Raphanus sativus* L.) in arid western Rajasthan

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Abstract

A field experiment was conducted during *Kharif* season 2004 and residual radish crop during winter season of 2004-05 to find out the effect of vermicompost levels and fertilizers combinations (NPK) on yield attributes and yield of okra [*Abelmoschus esculentus* (L.) Monech] and its residual effect on radish (*Raphanus sativus* L.). Application of increasing levels of vermicompost up to 6 t ha^{-1} significantly enhanced the nitrogen, phosphorus and potassium uptake of plants and yield and provided better economic return of okra. The B:C ratio was found to be highest by application of vermicompost at 3 t ha^{-1} in okra crop. Net return, B:C ratio and yield of residual crop radish were also increased significantly with increasing levels of vermicompost up to 6 t ha^{-1} in main crop. Further an application of fertilizer combinations up to 60:30:30 kg NPK ha^{-1} significantly enhanced the nitrogen, phosphorus and potassium uptake of plants and yield of okra. The root yield, net return and B:C ratio of residual crop radish also increased significantly with increasing levels of fertilizer combinations up to 30:15:15 kg NPK ha^{-1} applied in preceding crop.

Key words : Fertilizer, okra, radish, vermicompost, nutrient management, economics

The world's arable land resources are finite and there is not much scope for significantly expending the area of land under cultivation. Hence, most of the increase in agricultural production will have to be obtained through increased productivity from the existing agricultural land. This can be achieved by fertilizer management practices in particular. Okra [*Abelmoschus esculentus* (L.) Monech] commonly known as *bhindi*/lady's finger is grown through out the country as an important summer vegetable. It is well documented that the growth and yield of crop plants are greatly influenced by a wide range of nutrients. Adequate supply of nutrients is considered important for realizing the maximum yield in crops. Organic manure with chemical fertilizers and their method of application help in improving the fertility and productivity and physical condition of soil (Abusaleha and Shamugvelu, 1988) and low nitrogen loss due to slow release of nutrients from organic manures is an additional advantage. Presently, vermicompost is widely used for cultivation of vegetables, fruits, flowers, spices and medicinal plants. It is a rich mixture of major and minor plant nutrients. On an average, vermicompost contains 1.87 percent nitrogen, 1.26 percent phosphorus and 1.20 percent potassium. (Reddy and Reddi, 2002).

Vegetable and vegetable based cropping system show that vegetable crops respond well to nutrient supply through organic manures and chemical fertilizers (Kala *et al.*, 1991). Okra-radish crop rotation can be beneficial for vegetable growers under arid irrigated conditions of Bikaner. Radish grown on residual effect of applied vermicompost and fertilizers to okra can add more benefit to the marginal vegetable growers. Radish is a herbaceous crop belong to the family cruiciferae. It is a root-cum leafy vegetable suitable for tropical and temperate climate. Its plant is green and leafy with long white edible root. Thereafter, the present investigation was undertaken to find out the effect of integrated nutrient management on nutrient uptake and economics of okra [*Abelmoschus esculentus* (L.) Moench] and its residual effect on radish (*Raphanus sativus* L.) in arid region of Rajasthan.

MATERIALS AND METHODS

The experiment was conducted at College of Agriculture, Bikaner during *Kharif* season 2004 and residual radish crop during winter season of 2004-05. The soil was loamy sand and low in organic matter. The soil pH was 8.4. It was low in organic carbon (0.09 %), available nitrogen (64.40 kg ha^{-1}) and available phosphorus (9.80 kg ha^{-1}) and medium in potassium (151.34 kg ha^{-1}). The treatments comprised four levels of vermicompost (0, 3, 6 and 9 tonnes per hectare) and four combinations of fertilizers (0, 30:15:15 kg NPK ha^{-1} , 60:30:30 kg NPK ha^{-1} and 90:45:45 kg NPK ha^{-1} were laid out in randomized block design with three replications. Nitrogen as per treatments was applied through urea in two split doses i.e. one at the time of sowing and another at 30 days after sowing the main crop. Phosphorus, potassium and vermicompost were applied at the time of sowing the main crop. Okra variety VRO 6 (proposed name - Kashi Pragati) was sown at 30 x 30 cm spacing using 10 kg seed ha^{-1} on 18.08.2004. In rabi season, in the same field, radish variety Japanese white was grown on 04.12.2004 as the residual crop following same layout plan as that for okra. The data of yield attributes and yield was observed of main crop at first picking and residual crop at harvest.

RESULTS AND DISCUSSION

Effect of vermicompost

Application of increasing levels of vermicompost at 6 t ha^{-1} enhanced the nitrogen, phosphorus and potassium uptake of plants, yield and economics of okra. The effect of different levels of vermicompost from 0 to 6 t ha^{-1} was significant to each other; however, the effect of 9 t ha^{-1} was found to be at par with 6 t vermicompost ha^{-1} (Table 1). The magnitude of increase under 6 t vermicompost ha^{-1} were 48.29 and 11.16 per cent in nitrogen uptake, 51.67 and 14.72 per cent in phosphorus uptake , 52.12 and 14.84 per cent in potassium uptake, 37.59 and 9.86 per cent in yield and 35.75 and 6.62 per cent in net return of okra over control and 3 t vermicompost ha-1, respectively. However, the B:C ratio was found to be highest in vermicompost at 3 t ha^{-1} in okra crop. Further,net return, B:C ratio and yield of residual crop radish also increased significantly with increasing levels of vermicompost up to 6 t ha^{-1} in main crop (Table 1). The significant increase due to application of vermicompost at 6 t ha^{-1} was 29.05 and 10.24 per cent net return, 37.38 and 12.66 per cent B:C ratio and 37.25 and 12.71 per cent yield of residual crop radish as compared to control and vermicompost at 3 t ha^{-1}, respectively. It might be due to beneficial effect of vermicompost in supplying plant nutrients and increasing greater partitioning of metabolites towards sink (fruits) and adequate transformation of nutrients in accumulating dry matter in plants. The vermicompost provide adequate supply of macro and micro nutrients to the plants by the soil and makes a favorable environment to the soil activities. By this, plants metabolites activities rapidly increased and dry matter accumulation in the plants increased at early growth stages. The increment in dry matter in plants symmetrically increased the moisture content in fruits at first picking. These results are in agreement with the findings of Gupta *et al.*, (1999) in onion and Prabu *et al.*, (2003) in okra. It is obvious that pods yield increased with the incorporation of vermicompost in the soil which enhanced the net returns and B : C ratio (Usha Kumari *et al.*,1999) .

Effect of fertilizers

Further an application of fertilizer combinations up to 60:30:30 kg NPK ha^{-1} significantly enhanced the nitrogen, phosphorus and potassium uptake of plants, yield and economics of okra. The effect of different levels of fertilizer combinations up to 60:30:30 kg NPK ha^{-1} was significant to each other; however, the effect of 90:45:45 kg NPK ha^{-1} was found to be at par with 60:30:30 kg NPK ha^{-1} (Table 1). The

Table 1. Effect of organic and inorganic sources of nutrients on Nutrient Uptake by plants, yield and economics of okra and its residual effect on succeeding radish crop

Treatments	Preceding crop okra						Succeeding crop radish		
	Nutrient Uptake by plants (kg ha^{-1})			Yield (q ha^{-1})	Net return (Rs. ha^{-1})	B:C Ratio	yield (q ha^{-1})	Net return (Rs. ha^{-1})	B:C Ratio
	Nitrogen	Phosphorus	Potassium						
Vermicompost (t ha^{-1})									
V_0	168.44	37.16	185.07	68.26	46594	2.14	161.86	37734	3.49
V_1	224.71	49.13	245.16	85.49	59323	2.25	189.47	46016	4.25
V_2	249.78	56.36	281.53	93.92	63252	2.06	208.88	51840	4.79
V_3	260.11	59.21	295.79	97.50	62342	1.77	212.35	52882	4.89
SEm±	17.255	3.938	19.928	1.934	5543.4	0.209	5.539	4762	0.439
C.D. at 5 %	17.389	3.968	20.083	5.587	5587	0.211	15.997	4799	0.443
Fertilizers (kg ha^{-1})									
F_0	157.85	36.28	180.75	70.50	43217	1.59	166.51	39127	3.61
F_1	211.94	47.55	237.14	80.56	52461	1.88	189.93	46155	4.26
F_2	258.54	57.51	287.20	94.87	66077	2.33	204.31	50469	4.66
F_3	274.71	60.53	302.46	99.24	69755	2.41	211.81	52719	4.87
SEm±	17.255	3.938	19.928	1.934	5543.4	0.203	5.539	4762	0.439
C.D. at 5 %	17.389	3.968	20.083	5.587	5587	0.211	15.997	4799	0.443

magnitude of increase under 60:30:30 kg NPK ha^{-1} were 63.79 and 21.99 per cent in nitrogen uptake, 58.52 and 20.95 per cent in phosphorus uptake, 58.89 and 21.11 per cent in potassium uptake, 34.57 and 17.76 per cent in yield, 52.90 and 25.95 per cent in net return and 46.54 and 23.94 per cent in B:C ratio of okra over control and 30:15:15 kg NPK ha^{-1}, respectively. Further, root yield, net return and B:C ratio of residual crop radish also increased significantly with increasing levels of fertilizer combinations up to 30:15:15 kg NPK ha^{-1} in main crop (Table 1). The significant increase due to application of fertilizer combinations up to 30:15:15 kg NPK ha^{-1} was 22.70 per cent root yield, 28.99 per cent net return and 29.09 per cent B:C ratio of residual crop radish as compared to control. The beneficial effects of fertilizers on these parameters might be due to its contribution in supplying additional plant nutrients. It could be efficient and greater partitioning of metabolities and adequate transformation of accumulated dry matter which led to increased length and width and weight of fruits. The fertilizers provide adequate supply of major nutrients to the plants and makes a favourable environment to the physical and biochemical process and dry matter accumulation in the plant parts. These results are in agreement the findings of Farag and Damrany (1994) and Singh (2001) in okra.

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Effect of plant density on lac yield of *Femingia semialata* Roxb

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ABSTRACT

Optimum plant density of *Flemingia semialata* Roxb., a quik growing bushy host of Indian lac insect (*Kerria lacca* Kerr.). was determined for intensive lac cultivation of kusmi strin under rainfed condition by taking five densities *viz.*, 40, 000, 30, 000, 10,000,6,660 and 5,000 plants/ ha. The highest broodlac and sticklac yield to the extent of 437 and 193.5 g per bush respectively, was obtained at the lowest density which was 65.5 and 51.1 percent higher than that of highest densities (40,000) plants/ha. The broodlac and sticklac yield per bush standing at par with densities 40,000, 30,000 and 10, 000. On the other hand, the highest density had yielded maximum yield of broodlac and sticklac on hectare basis. The effect of plant densities on growth attributes of *F. semialata* and lac yield has been discussed.

Key words : Plant density, lac yield

Lac, the versatile and valuable resin of commerce of insect origin, is now gaining importance due to its eco-friendly properties in the present days of environmental consciousness. The Indian lac insect, *Kerria lacca* (Kerr.) (Homoptera: Techardiidate) is traditionally cultivated on tree host species such as kushum (*Schleichera oleosa*), ber (*Zizyphus mauritiana*) and palas (*Butea monosperma*). Since lac cultivation on these hosts is suffering due to gradual decrease in host population, problems in management and long gestation period before crop inoculation, intensive lac cultivation on quick growing bushy hosts in considered to be the only possible solution for increasing lac production for keeping pace with the growing global demand of lac. Out of many quick growing hosts identified for intensive lac cultivation, *Felemingia semialata* Roxb. (*Papilionaceae*) has a good potential for world best quality kusmi lac production on plantation basis (Kumar *et et.*, 1997). The work reported here was taken up for determining optimum plant density for *kusmi* lac production under rainfed condition during winter season to make efficient use of available resources by raising its plantation.

MATERIALS AND METHODS

An experiment was laid out under randomized block design with five treatments (densities) and four replications. Seedlings of *F. Semialata* were planted under five densities *viz.* 40,000; 30,000; 10,000; 6,660 and 5,000 Plants/ha, at a spacing of 0.5x0.5 m, 0.5x0.5 m (Skipping one row), 1.0x1.0m, 1.5x1.5m and 2.0x2.0m, respectively in the experimental area of 240 m^2 designated as D_1, D_2, D_3, D_4 and D_5, respectively, adopting the recommended package of practices (Singh, 2002) during July 2003 at the Research Farm of Indian Institute of Natural Resins and Gums, Namkum, Ranchi, Jharkhand (650m, 23° 2' N, 85° 2' E). Observation on number of shoots per bush, plant height and diameter of shoot was recorded at 3,12 (prior to lac inoculation) and 18 (at harvest) month after planting by simple measurement. Plants were inoculated by tying bundles of 30g broodlac (lac encrustation carrying gravid females) per bush during end of July 2004 for raising winter-season *kusmi* lac crop. Insect pest management was carried out by using the recommended practices for winter *kusmi* crop (Mishra, 2002). Data on broodlac yield was recorded just after harvesting of the crop on maturity during end February 2005 and that of

Table 1. Effect of plant density on the plant growth attributes of *Flemingia semialata*

Density (plants/ha)	Average number of shoots/bush			Average shoot girth (cm)			Average plant height (cm)			Total freshplant biomass at harvest	
	Growth stage (months)									g/bush	q/ha
	3	12	18	3	12	18	3	12	18		
40,000 (D_1)	2	3	3	1.9	3.4	5.4	5.1	131	174	574	230
30,000 (D_2)	2	3	3	1.8	3.4	5.7	48	135	154	570	171
10,000 (D_3)	3	3	3	1.7	3.8	6.1	43	134	152	616	62
6,660 (D_4)	3	3	3	1.8	3.7	6.3	47	135	160	932	62
5,000 (D_5)	3	4	4	1.8	4.5	7.2	47	144	170	953	48
LSD (P=0.05)	NS	NS	NS	NS	0.44	0.66	NS	5.04	13.1	127.4	-

sticklac (Scraped lac from lac stick after swarming of larvae) after 21 days of harvesting.

RESULTS AND DISCUSSION

Effect on growth attributes

Perusal of Table 1 indicated that, the effects of plant densities on average shoot number per bush at all the stages and plant height and average shoot girth at three month stage was found to be non-significant. At 12 and 18 months stage, the highest shoot girth to the tune of 4.5 and 7.2 cm, respectively, was recorded at lowest density (D_5), whereas remaining densities were found at par among themselves. Similarly, the highest value of plant height (144 cm) was recorded with lowest density and lowest (131 cm) with highest density at 12 month stage. At this stage, the maximum plant height was observed with lowest density and was significantly higher than other densities, but however, other densities did not differ significantly among themselves. While at 18 month stage, reverse was true and D_1 and D_5 being at par showed maximum plant height but other treatments were remained at par. Under highest plant density, the encrustation length per bush was less in comparison to that of lowest density, which might be the reason for their growth even after lac inoculation.

Plants under D_5 yielded highest fresh harvested biomass to the tune of 953 g per bush on accont of more number of shoots per bush, height and girth of shoots. On the other hand, lowest plant fresh biomass of 57 g per bush was found in D_2, Which was at par with D_1 and D_3. However, highest yield of plant biomass (230 q) was recorded per hectare in case of D_1 mainly due to accommodating more number of plants per unit area.

Table 2. Lac yield and yield attributes of *Flemingia semialata* as affected by different densities

Density (plants/ha)	Broodlac yield		Sticklac yield		Length of encrustation (cm/bush)	Sticklac yield (g/100g broodlac)
	g/bush	q/ha	g/bush	q/ha		
40,000 (D_1)	264	106	128.1	51	28	47.5
30,000 (D_2)	213	64	103.5	31	31	47.2
10,000 (D_3)	228	23	105.0	11	37	44.5
6,660 (D_4)	342	23	155.5	10	39.5	43.5
5,000 (D_5)	437	22	193.5	10	45.5	42.9
LSD (P=0.05)	87.21	-	38.75	-	8.47	3.2

Effect on lac yield

It is evident from Table 2 that broodlac and sticklac yield varied significantly due to various densities. The broodlac and sticklac yield significantly increased with increasing plant densities on hectare basis, thought the trend was reverse with per bush basis. Maximum value of broodlac and sticklac to the tune of 437 and 193.5 g per bush respectively was found at density D_5 however only sticklac yield was at par with density D_4. The plant density at D_5 showed significantly highest length of encrustation (45.5 cm/bush) at maturity that was significantly higher than that of D_3 and at par with D_4 which themselves were at par. Although, the individual yield performing characters with respect to lac yield was better at low densities except sitcklac per 100g broodlac but the total plant population per unit are at higher densities were perhaps played a positive and decisive role in contributing towards the higher yield at D_1 D_2 densities than at lower densities (D_3, D_4 & D_5). Sevi *et al.*, (2004) also reported from Turkey that highest seed yield (1708 kg/ha) of sesame (*Sesamum indicum* L.) was recorded with highest planting density (5, 10,000 plants/ha).

From this experiment, it can be concluded that, *F. semialaa* can be planted adopting compact densities for higher lac productivity as per the available resources under rainfed condition.

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Effect of dose, time and integrated nitrogen management on nitrogen use efficiency, optimum dose and economics of soybean

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Soybean [*Glycine max* (L.) Merr.], apart from high yield potential possesses very high nutritional values. It contains 20 percent oil and 40 percent protein of high quality. Soybean builds up the soil fertility by fixing large amount of atmospheric nitrogen through the root nodules and also through the leaf fall on the ground at maturity. Integrated plant nutrient system, inorganic and biofertilizer, increases nutrient use efficiency and provides greater stability in crop production. Though soybean is a legume crop, it requires starter does of nitrogen in addition to inoculation for better plant growth and establishment (Caliskan *et al.*, 2008). However, the application of nitrogen through chemical fertilizer increases the production cost beside the negative effects on soil properties in long run. Higher nitrogen application, combined with inoculation, increased dry matter, N-uptake, bean yield, pod number, bean weight and nitrogen content of seed (Kang, 2009). Therefore, an experiment was planned to study the influence of Rhizobium seed inoculation under varying levels and time of nitrogen application, so that efficiency of nitrogen fertilization can be increased with the added advantage of increased production.

The field experiment was conducted at the Agronomy research farm of Ch. Charan Singh Haryana Agricultural University, Hisar (29° 10' N, 75° 48' E and 215 M above mean sea level) during kharif season of 2009. The experiment was laid out in randomized block design (RBD) with 17 treatments replicated thrice. The treatments comprised four nitrogen levels *viz.*, 20, 40, 60 and 80 kg/ha applied full as basal at sowing, half as basal + half at 50 DAS and half as basal + half at 80 DAS along with Rhizobium inoculation alone and in combination with 20, 40, and 60 kg/ha levels of nitrogen in addition to a control. The soil of experiment field was sandy loam in texture and slightly alkaline in reaction (pH 7.7). As regards to fertility status the soil was low in available nitrogen, medium in available phosphorus, available potassium and organic carbon 155.4, 20.3, 254.8 kg/ha and 0.40% respectively.

Soybean variety JS-335 was sown in the third week of July by using 80 kg seed/ha at row spacing of 30 cm and thinning was done after 15 days of sowing to maintain plant to plant spacing of 10 cm. The total rainfall received during the growing season of crop at Hisar was 320.7 mm in 21 rainy days. The crop was raised with standard agronomic practices except for the treatments. Nitrogen use efficiency and recovery were calculated by using standard formula. Economic dose for soybean crop were calculated by fitting the quadratic response curve through the regression equation ($y = a + bx - cx^2$). The economics of various treatments were worked out on the basis of mean seed yield per hectare. The B:C ratio was computed by dividing the gross monetary return with cost of cultivation.

Apparent nitrogen recovery, agronomic efficiency and physiological efficiency were found to decrease with increasing levels of nitrogen (Table 1). Apparent nitrogen recovery and agronomic efficiency were maximum and significantly higher with 20 kg N/ha and inoculation (T_7) than all other treatments. While, physiological efficiency was maximum and significantly higher in Rhizobium inoculation alone (T_6) than all other treatments. Split application of nitrogen at 50 DAS improved nitrogen recovery slightly, but, did not affect agronomic and physiological efficiency of

Table 1. Effect of inoculation, dose and time of nitrogen application on nitrogen use efficiency and economics of soybean

Treatment	Grain yield (kg ha^{-1})	Nitrogen use efficiency ANR (%)	AE (kg kg^{-1})	PE (kg kg^{-1})	Economics (Rs.ha^{-1}) Cost of cultivation	GMR	NMR	B:C ratio
T_1 : control	1405	-	-	-	12984	36326	23342	2.80
T_2 : 20 kg N/ha as basal dose	1610	116	10.2	8.5	13201	41325	28124	3.13
T_3 : 40 kg N/ha as basal dose	1730	91	8.1	8.8	13418	44095	30677	3.29
T_4 : 60 kg N/ha as basal dose	1813	77	6.7	8.7	13636	46100	32464	3.38
T_5 : 80 kg N/ha as basal dose	1891	77	6.0	7.8	13853	48031	34178	3.47
T_6 : Rhizobium alone	1547	-	-	10.5	13059	39798	26739	3.05
T_7 : 20 kg N + Rhizobium	1696	168	14.5	8.6	13276	43259	29983	3.26
T_8 : 40 kg N + Rhizobium	1893	135	12.2	8.9	13493	47758	34265	3.54
T_9 : 60 kg N + Rhizobium	1968	126	9.3	7.4	13711	49640	35929	3.62
T_{10}: 10 +10 kg N/ha as basal & 50 DAS	1620	127	10.7	8.4	13501	41361	27860	3.06
T_{11} : 20 +20 kg N/ha as basal & 50 DAS	1735	99	8.2	8.3	13868	44076	30208	3.18
T_{12} : 30 +30 kg N/ha as basal & 50 DAS	1843	86	7.3	8.3	14236	46558	32323	3.27
T_{13} : 40 +40 kg N/ha as basal & 50 DAS	1915	83	6.3	7.6	14603	48275	33672	3.31
T_{14} : 10 +10 kg N/ha as basal & 80 DAS	1548	102	7.1	6.4	13501	39808	26307	2.95
T_{15} : 20 +20 kg N/ha as basal & 80 DAS	1656	81	6.2	8.0	13868	42538	28670	3.07
T_{16} : 30 +30 kg N/ha as basal & 80 DAS	1796	80	6.5	8.0	14236	45891	31655	3.22
T_{17} : 40 +40 kg N/ha as basal & 80 DAS	1880	73	5.9	8.0	14603	47971	33368	3.29
C.D. (P=0.05)	115	8.4	0.78	0.25	130	981	894	0.06

ANR (%) = Apparent nitrogen recovery, AE (kg kg^{-1}) = Agronomic efficiency, PE (kg kg^{-1}) = Physiological efficiency, GMR = Gross monetary returns and NMR = Net monetary returns

nitrogen in soybean. The linear decline in apparent N recovery, agronomic efficiency and physiological efficiency of nitrogen with increased nitrogen dose indicate that whole of the N applied was not utilized by the crop as the partial requirement may be fulfilled by Rhizobium inoculation. Inoculation provided favourable conditions for the multiplication of nodule bacteria which in turn produced more number of nodules and thereby more nitrogen was fixed for the use of the plant in treatments T_6-T_9 over the treatments T_1-T_5. All this helped the plant in getting sufficient nitrogen. It was found that inoculation considerably increased efficiency and recovery of nitrogen, when nitrogen was applied at proper dose and did not suppress nodulation and fixation capacity of *Rhizobium* bacteria.

However, noticeable positive effect of split application of N at 50 DAS was obtained over basal application. But significantly poor response of nitrogen use efficiency in splitting at 80 DAS was must be due to low utilization of nitrogen applied at very late stage. Lack of positive response to higher N doses in this experiment may also be attributed to reducing biological fixation capacity under higher N environment.

Hence, application of starter N at low doses (20-40 kg/ha) is enough to harness maximum nitrogen use efficiency and its recovery under prevailing environmental conditions. This is in conformity of results reported by Osborne and Riedell (2006) and Caliskan *et al.* (2008).

Applications of different levels of nitrogen have significantly increased the gross and net monetary returns. It was found that each level of nitrogen resulted in extra rupees over control. This might be due to low additional cost of nitrogen increased the cost of cultivation very little in comparison to increase in yield. Application of 80 kg N/ha gave highest gross and net monetary returns per hectare. Inoculation and its combined application with nitrogen significantly increased the net monetary returns per hectare. Treatment T_9 gave maximum net monetary returns (Rs.35929/ha) followed by T_8 and T_5 as these treatments remained most efficient in affecting the growth and development of crop and finally increased the crop yield to maximum. It was found that inoculation of seed either alone or coupled with nitrogen gave extra net monetary returns over Rs. 3000 per hectare. Bhattacharya *et al.* (2008) also reported similar findings.

It is evident from the data that B:C ratio was increased significantly with increase in the dose of nitrogen either alone or in combination with *rhizobium*. However, it was not affected much by splitting of nitrogen dose at either of its application time. The favourable responses of crop to the combined application of nitrogen and inoculation has resulted in the highest profit per hectare area with the application of nitrogen @ 60 kg/ha + inoculation. This may be due to the fact that the nitrogen requirement of this crop is quite high which has further been substantiated by the linear response of crop to nitrogen application (fig. 1). Deshmukh *et al.* (2005) also reported higher benefit with inoculation and nitrogen application.

The yield responses to different levels of nitrogen were fitted into a regression equation ($y = 1405 + (200.6)\,x - (20.7)\,x^2$), ($r^2 = 0.77$). Analysis of regression equation showed that even with no fertilizer application, 1405 kg/ha of grain yield was obtained due to inherent soil fertility. There was linear increase in yield up to 60 kg N/ha. Subsequently, the response line was found to be curvilinear i.e. for every increase in fertilizer dose, the yield increased at decreasing rate. This is evident from the yield data in table 1 that there is non-significant increase in 80 kg over 60N/ha. Fitting of quadratic response curve with obtained yield at each level of nitrogen dose revealed that economic optimum and physical optimum dose of N for soybean crop were 93.5 and 98.3 kg N/ha, respectively. These results are in conformity with the findings of Kang (2009).

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Response of thylakoid bound ascorbate peroxidase under abiotic stress in two wheat genpotypes

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Environmental stresses disrupt photosynthesis and increase photorespiration, altering the normal homeostasis of cells and cause an increased production of reactive oxygen species (Miller *et al.*, 2010). Reactive oxygen species (ROS) such as ^{1}O2, H_2O_2, O2 ·- and HO ·, are toxic molecules capable of causing oxidative damage to proteins, DNA and lipids (Apel and Hirt, 2004). On the other hand, transient increases in ROS levels also have a vital role in stress signaling and thereby in the survival of plants under adverse environmental conditions (Dat *et al.*, 2000) . Both biotic and abiotic stresses usually lead to an enhanced ROS production; therefore ROS-scavenging mechanisms acting in different organelles play a major role in plant survival and productivity, particularly in extreme environments (Danna *et al.*, 2003). In plants, ROS levels are controlled via a versatile antioxidant network. Components of the antioxidant system reside in various cellular locations and include a range of enzymatic scavengers, such as superoxide dismutases (SODs), ascorbate peroxidases (APXs), peroxiredoxins (PRXs), glutaredoxins, glutathione peroxidases and catalases. In addition, several non-enzymatic antioxidants such as ascorbate, glutathione, tocopherols, carotenoids and phenolic compounds also contribute to the cellular redox balance (Mitler et al., 2004).

APX is thought to play the most essential role in scavenging ROS and protecting cells in higher plants, algae, euglena and other organisms. APX is involved in scavenging of H_2O_2 in water-water and ASH-GSH (ascorabte-reduced glutathione) cycles and utilizes ASH as the electron donor (Gill and Tuteja, 2010). Several APX (EC 1.11.1.11) isoforms exist in plants, three of which reside in chloroplasts. In Arabidopsis alone five isoforms viz a 38 kDa thylakoid bound APX (tAPX), a 33 kDa stromal APX (sAPX) which is dual targeted to chloroplasts and mitochondria, and a putative luminal APX each encoded by a single nuclear gene have been reported. Outside chloroplasts, 25 kDa APX1 and APX2 have been found in the cytoplasm (cAPX), and a 31 kDa APX3 is located in glyoxisomes (gmAPX) (Kangasjarvi *et al.*, 2008).

Danna *et al.* (2003) showed that hexaploid wheat (*Triticum aestivum*) expresses three homologous tAPX genes (*TaAPX-6A*, *TaAPX-6B*, and *TaAPX-6D*) mapping on group-6 chromosomes. The tAPX activity of a mutant line lacking *TaAPX-6B* was 40% lower than that of the wild type. When grown at high-light intensity, photosystem II electron transfer, photosynthetic activity and biomass accumulation were significantly reduced in this mutant, suggesting that tAPX activity is essential for photosynthesis. Reactive oxygen species and antioxidant machinery in abiotic stress including APX has been reviewed extensively by Gill and Tuteja (2010).

The Intergovernmental Panel On climate change (2009) indicates that rising temperature, drought, floods, desertification and weather extremes will severely affect agriculture which includes wheat. Although the influence of temperature varies during wheat developmental phases, its action remains crucial throughout the whole plant life cycle. A temperature between 17 and 23°C is generally recognized as the optimum range for wheat vegetative growth, whereas 0 and 37°C are considered the minimum and maximum tolerable limits, respectively (Rinalducci *et al.*, 2011).

As a first step towards deciphering tAPX mediated scavenging of ROS under abiotic stress in wheat, two genotypes, a drought tolerant cultivar 'C306' and a susceptible cultivar 'HD2687' were selected to analyze changes in expression of tAPX mRNA in response to a series of abiotic stresses using semi- quantitative reverse transcription polymerase chain reaction (RTPCR). Seeds were sown in pots in soil-rite and fifteen day old seedlings were exposed to high temperature (37°C) and low temperature (4°C) stress in a time course experiment. Plants at 20°C were taken as control for relative comparison and housekeeping gene tubulin was used as equal loading calibrator for RTPCR reactions. Leaf samples were harvested at the interval of 2 hrs, 6 hrs, 12 hrs and 24 hrs, frozen in liquid nitrogen and stored at -80°C till further use. In another set of pots H_2O_2 (0.5mM and 1mM) was applied exogenously and samples harvested and stored in a similar manner. RNA was isolated using Triazol reagent (Invitrogen) and reverse transcription was carried out using Superscript II enzyme (Invitrogen) using oligo dT primer and following manufacturer's instructions. For PCR amplification of tAPX, cDNA sequence cloned earlier in the laboratory (Accession number AY513262) was used to design forward and reverse primers namely F 5'TGGGATGGCATGATTCGGGTACAT 5' and R 5' TTGAAGAATGCACCCTGGTCCTCT 3' and used in a 50 µl PCR reaction volume containing Taq DNA polymerase (NEB).

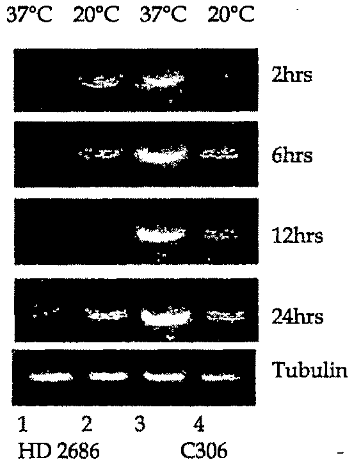

Fig. 1. RT-PCR analysis of tAPX in wheat genotypes at 37°C and 20°C .Lanes 1 and 2: 'HD 2687' exposed to 37°C and 20°C; lanes 3 and 4: 'C306' exposed to 37°C and 20°C respectively; lower panel amplification of tubulin transcripts used as equal loading and expression control

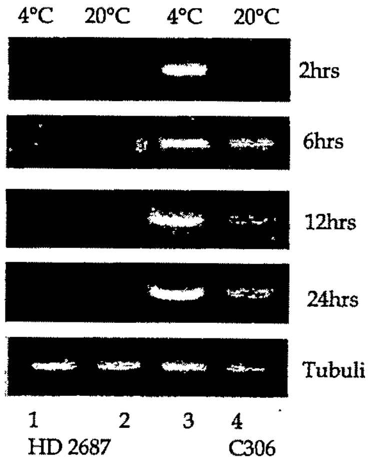

Fig. 2. RT-PCR analysis of tAPX transcripts in wheat genotypes at 4°C and 20°C. Lanes 1 and 2: 'HD 2687' exposed to 4°C and 20°C; lanes 3 and 4: 'C306' exposed to 4°C and 20°C respectively

Transcript expression profiling of wheat tAPX at varying time interval showed enhanced and differential expression under the above environmental modulation. Higher increases in steady-state transcript levels of the tAPX was observed in 'C306' than in 'HD2687' that could be corroborated to their respective tolerance to stress, suggesting a capacity to efficiently detoxify active oxygen species at their production site by the tAPX enzyme.

At 20°C regular temperature growth the cultivar 'HD2687' at different time points showed marginal expression of tAPX which were comparable to 'C306' under similar growth conditions. When exposed to high temperature at 37°C for varying period (Fig. 1), 'C306' showed enhanced transcript accumulation with maximum expression recorded at 24 hrs after stress exposure. In case of 'HD2687' no relative change was observed at 37°C with a visible lower modulation of tAPX after 6 hrs of exposure. Under continuous exposure to cold temperature at 4°C for 24 hours marginally higher expression profile of tAPX was observed in 'HD2687'. On the other hand 'C306' showed very high modulation in expression of tAPX from 2 to 24 hrs of continuous exposure (Fig. 2).

Leaves of fifteen day old seedlings were applied with H_2O_2 exogenously and samples

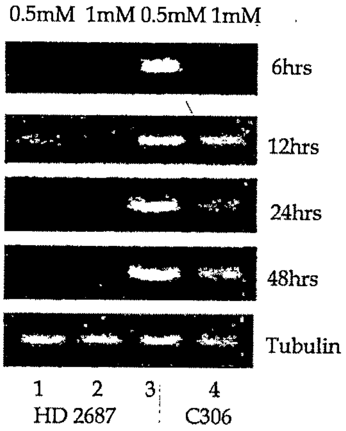

Fig. 3. RT-PCR analysis of tAPX transcripts in wheat genotypes after exogenous application of H_2O_2 .Lanes 1 and 2: 'HD 2687' exposed to 0.5mM and 1mM of H_2O_2; lanes 3 and 4: 'C306' exposed to 0.5mM and 1mM of H_2O_2 respectively

collected periodically. As can be observed from Fig. 3 there is not much change in tAPX transcript level in case of 'HD2687' at 0.5mM or 1mM concentration of H_2O_2 whereas 'C306' showed high accumulation of transcripts at 0.5mM concentration with a relative reduction in expression at 1mM of H_2O_2 exposure.

The stress acclimation and cross tolerance of wheat involve multiple H_2O_2 detoxification systems that prevent oxidative damage by controlling the level of H_2O_2 in chloroplasts. Climate changes emphasize the need to design new strategies for incorporating abiotic stress resistance in cultivated wheat. This calls for investigating and validating components of various stress combating mechanisms for further manipulation into crop plants for a resilient wheat production. The RTPCR analyses of tAPX in 'C306' and 'HD2687', can be used to summarize that tolerant genotype 'C306' has improved antioxidant machinery as compared to sensitive genotype 'HD2687'. The functional validation of tAPX in transgenic model plants under environmental stress will further dissect its protective effect in maintaining ROS balance and homeostasis in wheat plants.

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The author thanks Project Director, National Research Center on Plant Biotechnology, New Delhi for laboratory facilities

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Simulating the seepage from lined farm canal under shallow water table condition using HYDRUS 2D

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ABSTRACT

The study was conducted in the year 2007-08 to quantify the groundwater recharge dynamics. Experiments were conducted on a 7-year-old cement lined rectangular watercourse and 25-year-old brick lined trapezoidal farm minor. The initial water table was at 2.54 m below soil surface. The height of the bottom of the watercourse (H_o) from the water table was 2.43 m. A finite element flow model, HYDRUS-2D was used to simulate the drawup in observation well pressure heads during recharge from lined watercourses and farm canal under shallow water table condition. The physical flow region involved a soil profile of 200 m wide and 25 m deep with a canal placed at the top. Constant pressure head of 0.37 m and 0.79 m was given on the bottom of the canal for calibration and validation experiments. Saturated hydraulic conductivity was estimated through inverse modeling technique using the experimental pressure heads h time pairs during recharge from the lined watercourses and farm canal.

Low Root Mean Square Error (0.1-0.35) and high modeling efficiency (97.9-99.8%) for pressure head during recharge from the lined watercourses calibrated the model successfully. High mean modeling efficiency (99.0 - 99.9%) and low RMSE (0.05-0.36) of predicted and experimental pressure head value validated the HYDRUS 2D model for groundwater recharge from the lined farm canal. The model was used to predict the increase in radial influencing zone with increase in hydraulic conductivity and anisotropy of the surface soil layer. Critical water logging zone increased with increasing hydraulic conductivity and anisotropy of the surface soil layer. The study suggested that HYDRUS 2D may be adopted for simulations in ground water recharge studies.

Key words: Simulation, ground water recharge, lined watercourses, shallow water table, HYDRUS 2D.

The seepage could be an effective and eco-friendly measure for groundwater recharge in falling water table situations even after lining of watercourses (Anonymous, 1984). It can also be an effective measure for improving the groundwater quality where the groundwater is not fit for irrigation purpose due to brackish quality. Therefore, it is important for planning the areal groundwater recharge to quantify it as a result of seepage from the lined canal under different geo-hydrological condition.

A few studies have been conducted to quantify the seepage effect and groundwater recharge from unlined canals and watercourses (Phogat *et al.* 2000). To our knowledge, a little information is available on quantification of groundwater recharge from lined watercourses.

The two-dimensional numerical finite element HYDRUS 2D model developed by Simunek *et al.* (1996) is designed to handle unsaturated, partially saturated and fully saturated porous media and to handle flow domains delineated by irregular boundaries. In this study, HYDRUS 2D would be used to simulate the canal seepage and water table rise under shallow water table condition in a loamy soil in the field.

MATERIALS AND METHODS

Experimental set-up

An experiment was conducted in the year 2007-08 on a 7-year-old cement lined rectangular watercourse (width 2W = 0.6 m; constant water head ho = 0.37 m; design discharge = 0.023 m3/h) situated at an outlet number - RD 5500 L of farm canal and 25-year-old brick lined trapezoidal farm minor (surface width 2W = 4.95 m; side slope = 1:1; constant water head ho = 0.79 m; design discharge = 0.840 m3/s) passing through soil research farm CCS Haryana Agricultural University, Hisar. Soil samples from different layers, taken during the installation of observation wells were analyzed for different physico-chemical properties using standard methods Table 1.

Table 1. Relevant soil physico-chemical properties and hydraulic parameters used in field and numerical experiments

Parameters	EC (dS m^{-1})	pH	θr(m^3 m^{-3})	θs(m^3 m^{-3})	α(m^{-1})	n	Ks(m h^{-1})
Loam	1.2	8.2	0.03	0.47	0.05	2.2	0.042
Loamy sand	1.19	8.5	0.05	0.43	0.10	2.5	0.208
Clay loam	0.96	8.6	0.07	0.54	0.015	2.1	0.002

The initial water table was at 2.54 m depth from the soil surface. The height of the bottom of the watercourse Ho from the water table was 2.43. The saturated aquifer thickness e was 11.6 m and height of the bottom of the watercourse from the soil surface h_s was - 0.11 m as shown in Fig. 1(a).

Rise in water table were observed as a function of time t in observation wells placed at watercourse orthogonal distances X = 5, 25, 50 and 100 m as shown in Fig. 1(b) at different time intervals starting from t = 2 h for rise. Similarly rise in water table was observed as a function of time t in observation wells placed at farm canal orthogonal distances X = 10, 20, 40 and 60 m as shown in Fig. 1(c, d) at different time intervals starting from t = 6 h up to 138 h.

Parameter estimation

Soil water retention functions were derived from pressure head and water content data measured on pressure plate apparatus using Van Genuchten-Mualem equations (Van Genuchten, 1980) as:

$$\theta(h) = \frac{\theta s - \theta r}{[1 + |\alpha h|^n]^m} \qquad h<0 \qquad (1)$$

$$\theta(h) = \theta s \qquad h\geq 0 \qquad (2)$$

$$K(h) = KsSe^k\left[1 - \left(1 - Se^{k/m}\right)^m\right] \qquad (3)$$

where θ is the volumetric water content, h is the pressure head, α, n, m (m=1-1/n), and k (=0.5) are empirical parameters, Se= (θ- θr)/ (θs- θr) is the degree of saturation. For this purpose θr, is the residual water content and θs, the saturated water content. Saturated hydraulic conductivity was estimated through inverse modeling technique using the experimental pressure heads h time pairs during recharge from the lined watercourses and farm canal by using the observed θr, θs, α, n, and m as fixed parameters (Table 1). Estimation of hydraulic parameter through inverse modeling has become an accepted technique under field condition (Ghulam Ali et al. 2004).

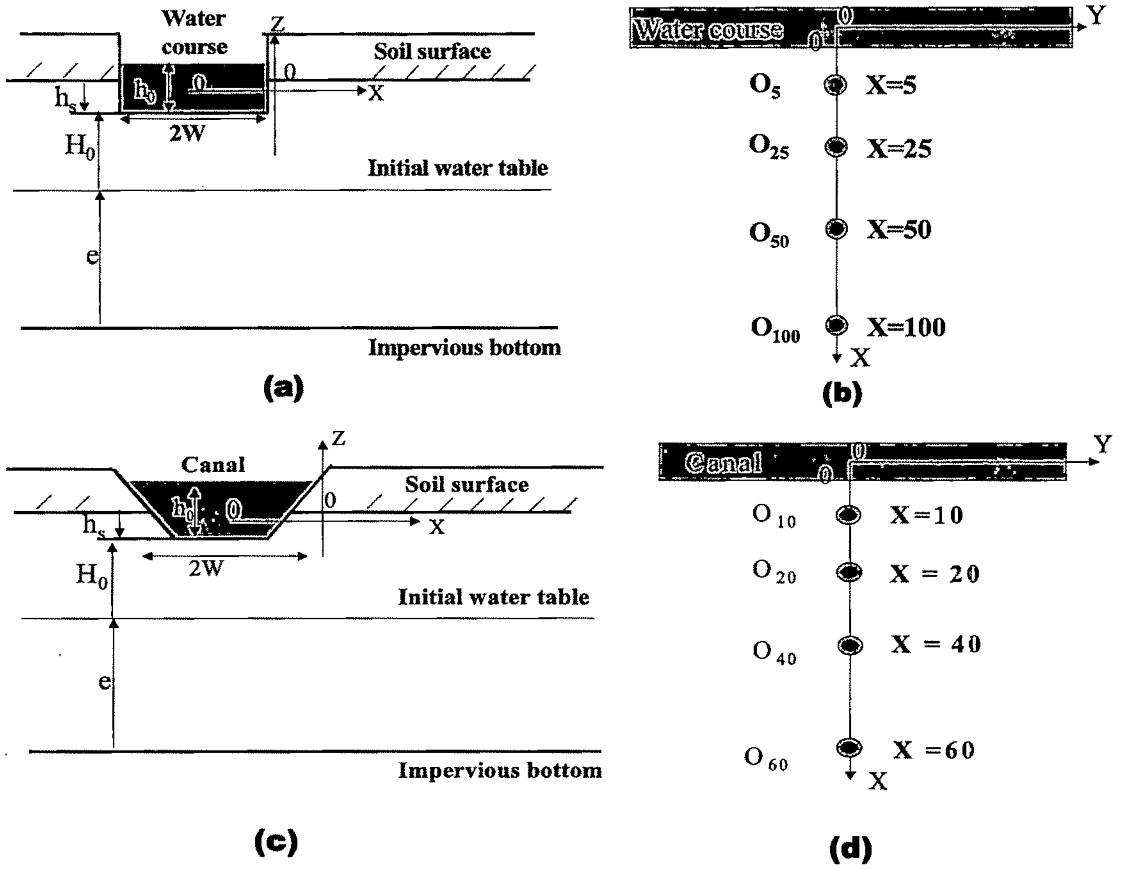

Fig. 1. Schematic diagram showing (a, c) watercourse positional parameters in horizontal X and vertical Z plane: water depth h_0, width 2W, height of the bottom from water table H_0, height of the bottom from soil surface h_s in watercourse and farm canal (b, d) observation wells position in horizontal X and watercourse length Y planes at indicated orthogonal distances in water course

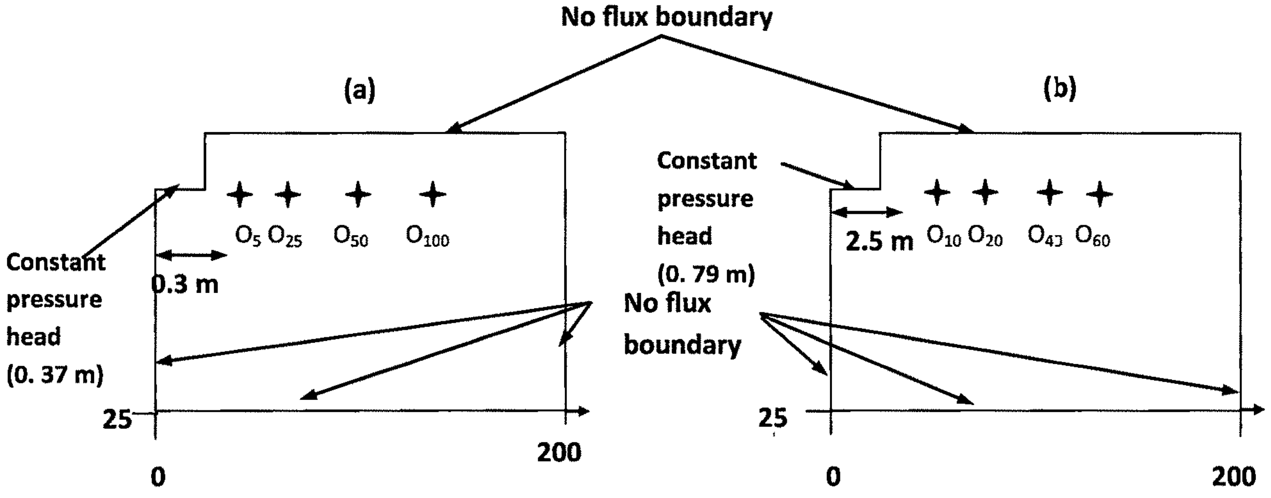
No flux boundary
(a)
(b)
Constant pressure head (0. 37 m)
0.3 m
O_5 O_{25} O_{50} O_{100}
25
0
200
Constant pressure head (0. 79 m)
No flux boundary
2.5 m
O_{10} O_{20} O_{40} O_{60}
25
0
200

Fig. 2. Schematic layout of the watercourses and farm canal position implemented in HYDRUS 2D during (a) calibration and (b) validation

Table 2. Calibration and validation statistical test during seepage from the lined canal and watercourses

Calibration			
	n	RMSE	ME (%)
O_5	22	0.1	99.8
O_{25}	22	0.35	97.9
O_{50}	22	0.26	97.9
O_{100}	22	0.13	99.7
Validation			
O_{10}	16	0.36	99
O_{20}	16	0.05	99.9
O_{40}	16	0.23	99.4
O_{60}	16	0.11	99.8

Model description

Initial boundary condition

The physical flow region involved a soil profile of 200 m wide and 25 m deep with a canal placed at top of the soil profile. No flux boundary condition was given at soil surface, bottom and lateral sides of the flow regions (Fig. 2). Constant pressure head of 0.37 and 0.79 m was given on the bottom of the canal for calibration and validation experiments. Observation well (O) served as the observation nodes at the position.

The windows based HYDRUS 2D package solves the modified form of Richard equation (1) for variably saturated flow numerically as:

$$\frac{\partial\theta}{\partial t}=\frac{\partial}{\partial x_i}[K(K_{ij}^{A}\frac{\partial h}{\partial x_j}+K_{iz})]-S \qquad (4)$$

where θ is the volumetric water content, h is the pressure head, S is the sink term, x_i ($i = 1,2$) are the spatial coordinates, t is the time, K_{ij}^{A} are the components of the anisotropy tensor K^A, and K is the unsaturated hydraulic conductivity.

Numerical experiments

The periodic field data collected at different time intervals from the observation wells at the onset of canal water in the watercourses was being used for calibrating the HYDRUS 2D model. Model was calibrated for increase in pressure heads during recharge in the observation wells which were installed at an orthogonal distances of X= 5, 25, 50 and 100 m from the watercourses. Similar experiments were also conducted to see the effect of seepage on increase in pressure heads in the observations wells installed at an orthogonal distances of X = 10, 20, 40 and 60 m from the farm canal. The data from these observation wells were used for validating the HYDRUS 2D model for increase in pressure heads.

Statistical test

Statistical tests to assess simulation performance were:

Modeling efficiency (ME)

$$ME=1-\frac{\sum_{i=1}^{n}(O_i-S_i)^2}{\sum(O_i-\bar{O})^2} \qquad (5)$$

where Oi and Si represent the observed and simulated values, n represents the number of observed and simulated values used in the comparison, and $\bar{O}$ the observed average

$$RMSE=\sqrt{\left(\frac{1}{n}\sum_{i=1}^{N}[O_i-S_i(b)]^2\right)} \qquad (6)$$

Results and Discussion

Calibration

Optimized field saturated hydraulic conductivity was obtained from pressure heads and time data pairs during the recharge from the canal by inverse modeling technique of HYDRUS 2D using θr, θs, α, n, and m (derived experimentally) as fixed parameters. Low RMSE (0.1-0.35) and high modeling efficiency ME (97.9-99.8) for observation well pressure head during recharge from the lined watercourses (Table 2) calibrated the model, indicating high degree of

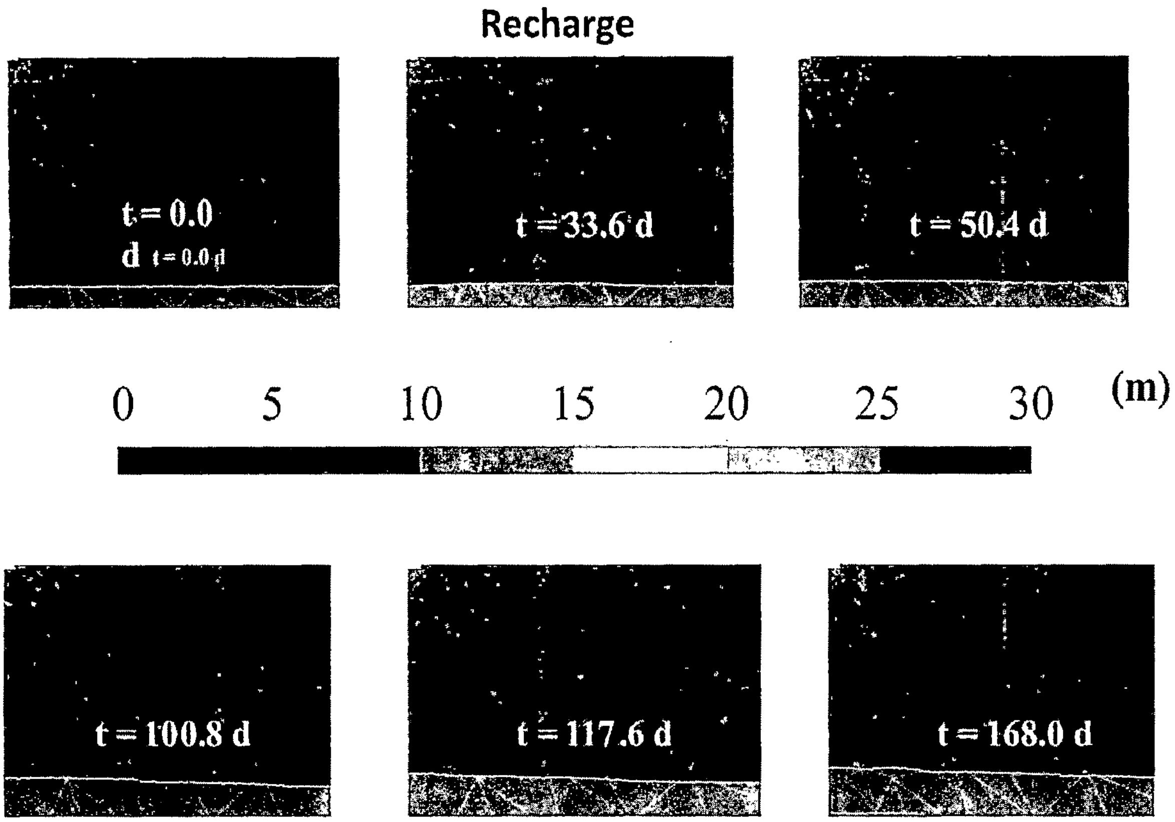

Fig. 3. Development of pressure isolines at increasing time of recharge from the lined watercourses as a function of time

accuracy of obtaining field saturated hydraulic conductivity from inverse modeling during recharge from watercourses.

Draw up increase with time and decrease with radial distance during recharge (Fig. 3) from the lined watercourses. The rising iso-pressure lines with the time of recharge (Fig. 3) indicate the increase in drawup with recharge time on the onset of canal. This is because of increase in groundwater level due to seepage from the canal with time during recharge. The negative slope of pressure isolines at any particular time (Fig. 3) shows the pressure decreased with radial distance during recharge. For simulating temporal pressure for a longer period of time of 1-10 years, this model has to take in to account naturally occurring recharge (rainfall, irrigation etc.) processes. Hence the use of HYDRUS 2D model in this study is justified for groundwater recharge.

Validation

Saturated hydraulic conductivity values obtained in the calibration of the model in the recharge process from watercourses were used for validating the model in the recharge process from the farm canal. There was a good matching between experimental and simulated draw up in observation well pressure heads (Fig. 4) upon recharging from the lined farm canal. Pressure head increase with increase in time and decreased with increase in radial distance from the farm canal and water courses. High mean modeling efficiency (99.0 - 99.9) and low RMSE (0.05-0.36) of predicted and experimental pressure head value validate the HYDRUS 2D model successfully for groundwater recharge from the lined farm canal.

Successful calibration of the HYDRUS 2D model from the watercourses and validation

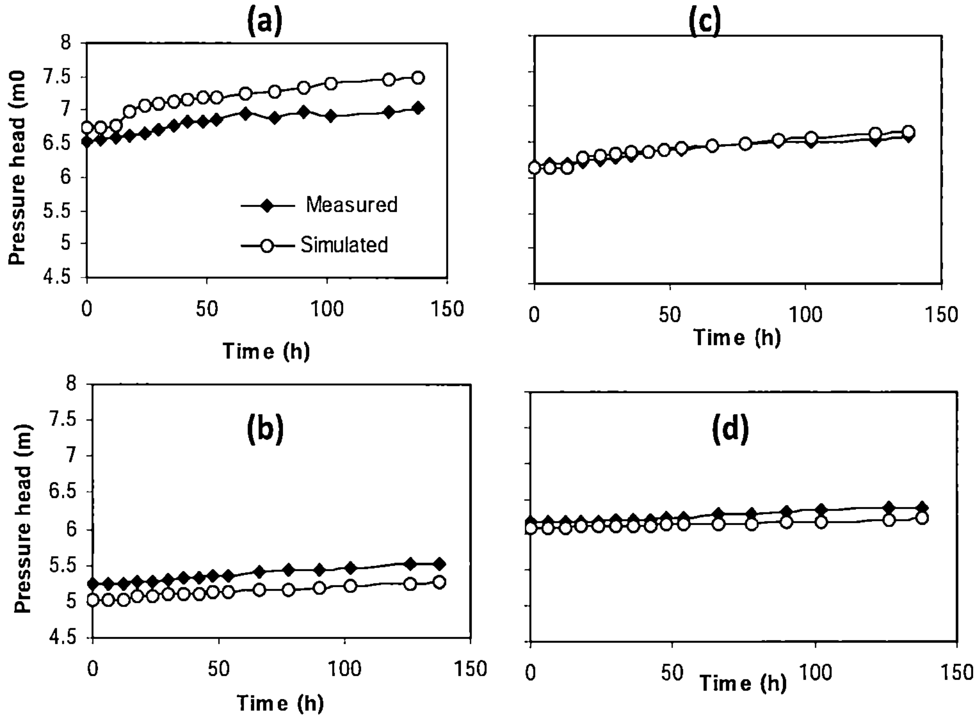

Fig. 4. Simulated versus measured draw up of observation well (a) O_{10}, (b) O_{20}, (C) O_{40} and (d) O_{60} pressure head upon recharging the aquifers from the lined farm canal as a function of time

from the farm canal implied that the model may be used for simulating spatial and temporal groundwater responses to recharge from the farm canal. It may be further seen that the method of estimating hydraulic conductivity from inverse modeling technique through HYDRUS 2D was satisfactory for simulating drawup from the farm canal even up to a longer period of 300 days or more. The extent of RMSE and ME did not vary with the recharge from the water courses and farm canal, which further confirmed the validity of the model over longer period of time. Thus, HYDRUS 2D may be used for projecting and optimizing the operational factors like the amount of water to be recharged and the residence time of the recharge for the success of recharge process from the lined farm canal. So far, the model has been used for predicting the water salt and heat balance studies and pressure distributions mostly in the unconsolidated zone (Manglik *et al.* 2004). Only few applications to simulate groundwater recharge have been reported from the lined canals (Khair *et al.* 2000).

Model projection

The model is used to project the effects of geo-hydrological parameters: saturated hydraulic conductivity and anisotropy on radial influencing zone and critical water zone. Radial influencing zone r_{iz} is taken as that radial distance z up to which there is 5% of maximum draw up during recharge. Critical water logging zone C_{iz} is that distance from canal and watercourse at which water table depth becomes just one meter from soil surface.

Saturated hydraulic conductivity: The radial influencing zone r_{iz} increased slowly with increase in hydraulic conductivity of the surface soil layer (0-9.6 m) from 0.01 to 0.1 m/h and increase sharply with increase in hydraulic conductivity from 0.1 to 0.5 m/h (Fig. 5a). Critical water logging zone C_{iz} increased with increasing hydraulic conductivity. It means that canal have more influencing zone and water logging effect in sandy soil than in clayey soil.

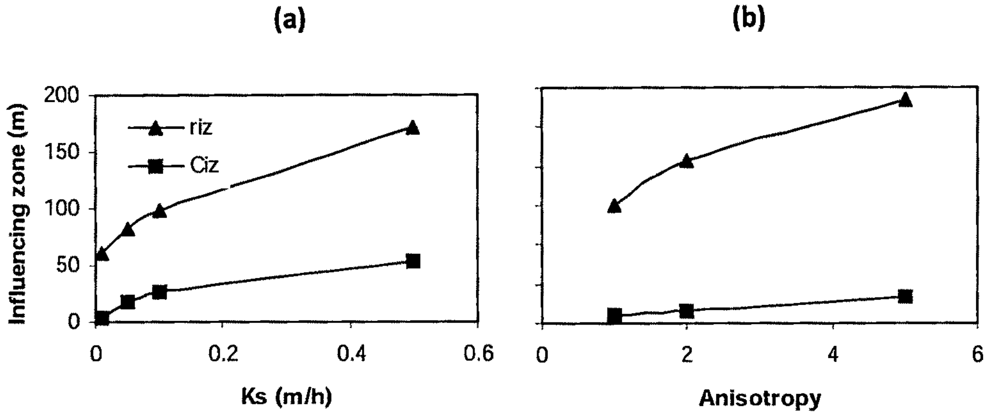

Fig. 5. Model projection of radial influencing zone r_{iz} and critical water logging zone C_{iz} as a function of (a) aquifer hydraulic conductivity, Ks (b) aquifer anisotropy

Anisotropy: The radial influencing zone riz increase sharply with increase in anisotropy from 1 to 5 (Fig. 6b). Critical water logging zone Ciz increased with increasing anisotropy. It means that canal have more influencing zone and water logging effect in soils having more anisotropy than in soils with less anisotropy.

Rastogi and Prasad (1992) also showed that the canal supply depth or aquifer hydraulic conductivity had more influence on seepage flux value from the lined canal than the other operational factors.

CONCLUSION

1. HYDRUS 2D simulated the drawup of pressure head quite well during the whole period of time of recharge from lined farm canal and watercourses.

2. Radial influencing zone increased with increasing saturated hydraulic conductivity and anisotropy of the surface soil.

3. Critical water logging zone C_{iz} also increased with increasing saturated hydraulic conductivity and anisotropy of the surface soil.

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Effect of sulphur on growth and yield of sunflower (*Helianthus annuus* L.) and blackgram (*Phaseolus mungo* L.) in intercropping system

Promod Kumar and O.V.S. Thenua

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ABSTRACT

Two year field experiments were conducted during *kharif* 2006 and 2007 at the research farm of A.S. Post Graduate College, Lakhaoti to find out suitable planting pattern for sunflower and blackgram under intercropping for increased productivity and land use efficiency. The experiment was laid out in split plot design with 3 replications. Quadratic response function was fitted to define the relationship between the seed yield and sulphur application and total productivity (sunflower equivalent) and sulphur application. The optimum economic dose of sulphur computed for sunflower and blackgram intercropping was 56.0 kg/ha.

Key words : Fertilizers, *Helianthus annuus,* intercropping, *Phaseolus mungo,* sulphur.

The sunflower (*Helianthus annuus* L.), introduced in India in 1969 for commercial cultivation, is now at second place in the world among oilseeds after soybean. It is grown extensively in Karnataka, Maharashtra, Tamil Nadu and Andhra Pradesh. The area is enhancing in the Uttar Pradesh, Punjab, Rajasthan, Haryana etc. It is rarely used as an intercrop, but it embodies the traits eminently suitable for intercropping (Robinson, 1984). Out of several grain legumes, sunflower gives more equivalent yield when intercropped with blackgram (*Phaseolus mungo*) since the peak growth period of these two crops does not coincide due to slow initial growth rate of sunflower and shorter duration and short statured nature of blackgram. The literature on such intercropping is scanty as only meager attempts have been made so far on the behavioral studies of the crop components involving sunflower and blackgram in pure and mixed stand. Keeping in view the importance of both oilseeds and pulses, it is imperative to develop suitable intercropping systems for higher productivity as well as sustainability. Sulphur also helps in metabolic activities of plant tissues and is involved in the formation of chlorophyll, vitamins and activation of certain enzymes. Besides it plays a significant role in nodule formation and biological N- fixation in legumes (Khandkar *et al.* 1985). The study was, therefore, under taken to find out suitable planting pattern for sunflower and blackgram under intercropping for increased productivity and land use efficiency.

MATERIALS AND METHODS

The soil of the experimental site was sandy loam in texture, medium possessed sulphur (7.2 ppm), phosphorus (10.8 kg/ha) and high potassium (279.0 kg/ha). The pH value, being 7.6 suggested that the soil was slightly alkaline. The experiment was laid out in split plot design with three replications (Table 1). The MSFH 8 hybrid sunflower, developed by the Maharashtra Hybrid Seed Company, was taken and its height was 150 cm tall and matures in 90 to 95 days. The T 9 blackgram seeds (containing about 24 to 25% protein) were taken and these were medium-sized and black. Their plants were semi-erect and leaves were black; and they matured between 60 and 65 days. The experimental field was disced twice by a tractor drawn disc, followed by harrowing with cultivator and planking with bullock drawn paata to provide a good tilth from 2006 to 2007. A basal dose of 20 kg N + 40 kg P_2O_5/ha was applied uniformly at planting through di-ammonium phosphate (DAP). The remaining 40 kg N/ha for sunflower was given at 30 days after sowing (DAS) on area basis through urea as top dressing. Sulphur was applied through gypsum as per treatment. Sunflower and blackgram were sown at a seed rate of 10 and 15 kg/ha, respectively, in sole plots. The population of the sunflower and blackgram were maintained as per treatments.

The gap filling was done after 7 days of sowing. To maintain the desired population as per the treatments, the thinning was under taken 15 days after sowing. The crops were given 2 hand weeding: first on 20th day after sowing and second on 30th day after sowing. The crops were given a foliar spray of malathion @ 2 ml/liter against insect pests. Fluchlorin was applied as pre-plant incorporation to control weeds. The net plots for sole crop and intercrop were harvested first and the border rows were harvested later. Quadratic response function was fitted to define the relationship between the seed yield and sulphur application and total productivity (sunflower equivalent) and sulphur application.

Quadratic equation $Y= a + bx +cx^2$

where, Y, Expressed yield (q/ha); x, unit of nutrient (kg); a, b and c are constants.

The economic optimum dose of fertilizer (kg/ha) was obtained by using the equation:

$X \text{ opt} = (q / p\text{-}b) \div 2 c$

where, b, and c are the two constants in the quadratic response function and q is the cost per unit of input and p is the price of output.

The response of optimum dose of fertilizer was obtained by using the equation:

Response at optimum dose = Y opt - Y control

Response per kg fertilizer at optimum dose was calculated as

= Y opt - Y control ÷ Y opt

The data collected in the experiment were analyzed by the analysis of variance technique, as suggested by the Cochran and Cox (1967). Wherever, variance 'F' values were found significant, critical differences (CD) at 5% level of probability were computed for making comparisons among treatments.

RESULTS AND DISCUSSION

The results suggested that 2:3 planting pattern recorded the highest productivity being significantly higher than sole sunflower and blackgram, and 1:2 and 1:3 planting patterns during 2006 and 2007 and in pooled analysis, (Table 2). Planting patterns of 1:1 and 2:3 were, however, at par in 2007 and in pooled analysis, (Table 2). The sunflower equivalent yield significantly increased by sulphur (S) application in 2006 and 2007 and in pooled analysis. The significant increase in sunflower equivalent was recorded with increasing levels of S up to 40 kg/ha only. All the planting patterns gave higher land equivalent ratio (LER) than sole crops. However, paired planting of sunflower with blackgram in 2:3 planting patterns recorded higher LER (1.38) than 1:1 (1.21), 1:2 (1.19) and 1:3 (1.11) planting patterns (Table 3). In all the planting patterns the coefficient was higher for sunflower which means sunflower was the dominated crop (Table 3). For the intercropping to be advantageous product of coefficients should be more than one, that means intercropping of sunflower and blackgram in all the planting patterns has definite yield advantage. It was more than one for sunflower and less than one for blackgram in all the planting patterns of intercropping showed that sunflower was the dominant crop whereas blackgram was a dominated crop (Table 3).

The higher values could be due to better and efficient utilization of growth resources, resulting from temporal and spatial complementarily (Willey, 1979). Among the planting patterns, the highest value of land equivalent ratio (1.38) was recorded in 2:3 row ratio of sunflower and blackgram intercropping. It was because of higher productivity resulting from 75% plant density of blackgram and 100% plant density of sunflower with a minimum shading effect, and better utilization of growth resources. Similar results were also reported by Ali and Mishra (1993), Ali *et al.* (1998) and

Table 1. Description of experimental treatments

S. No.	Treatments	Notation	Plant population		Total (%)		
			Sunflower	Blackgram	Sunflower	Blackgram	
A.	Planting patterns (main plot)						
1.	Sole sunflower (60 cm)	PP1 Sole SF	55,555	-	100.0	-	100.0
2.	Sunflower (60 cm)+ Blackgram (1:1)	PP2 SF +BG(1:1)	55,555	1,66,666	100.0	050.0	150.0
3.	Sunflower (90 cm)+ Blackgram (1:2)	PP3 SF +BG(1:2)	37,037	2,22,222	066.6	066.6	133.2
4.	Sunflower (120 cm)+ Blackgram (1:3)	PP4 SF +BG(1:3)	27,777	2,50,000	050.0	075.0	125.0
5.	Sunflower (40/80 cm)+ Blackgram (2:3)	PP5 SF +BG(2:3)	55,555	2,50,000	100.0	075.0	175.0
6.	Sole Blackgram (30cm)	PP6 Sole BG	--	3,33,333	--	100.0	100.0
B.	Sulphur (Sub-plot)						
1.	0 kg/ha	S_0					
2.	20 kg/ha	S_{20}					
3.	40 kg/ha	S_{40}					
4.	60 kg/ha	S_{60}					

Design : Split plot design

Number of replications : Three

Gross plot size	:(Treatments 1, 2, 3 5 and 6)	4.5 m × 3.6 m	=16.2 m^2
	(Treatment 4)	4.5 m × 4.8 m	= 21.6 m^2
Net plot size	:(Treatments 1, 2, 3, 5,and 6)	3.9 m × 1.8 m	= 07.02 m^2
	(Treatment 4)	3.9 m × 2.4 m	= 09.36 m^2
	(Treatment 5)	3.9 m × 1.2 m	= 04.68 m^2

Table 2. Effect of planting patterns and levels of sulphur on sunflower equivalent yield

Treatments	Sunflower equivalent yield (q/ha)		
	2006	2007	Pooled
Planting pattern			
Sole SF	13.30	17.16	15.23
Sole SF 60+GC (1:1)	14.84	19.60	17.12
Sole SF 90+GC (1:2)	13.06	18.24	15.65
Sole SF 120+GC (1:3)	11.82	16.19	14.00
Sole SF 40/80+GC (2:3)	16.25	20.67	18.46
Sole GC	07.85	10.85	09.35
SE m ±	00.26	00.35	00.21
C D (P=0.05)	00.84	01.12	00.77
Sulphur (kg/ha)			
0	10.12	13.87	12.00
20	12.34	16.59	14.46
40	14.26	18.85	16.55
60	14.54	19.15	16.85
SEm ±	00.21	00.30	00.19
C.D. (P= 0.05)	00.61	00.85	00.55

Kumar (2006). The value of index was in minus in all the planting patterns for blackgram which showed that blackgram was less competitive while reverse was true for sunflower as sunflower was dominant over blackgram in all the planting patterns, (Table 3). Dominant nature of sunflower might be due to its tall stature and resource exhaustive, whereas reverse was true for blackgram. However, their association was beneficial because of spatial and temporal complimentary between both crops and also having contrast nature to utilize natural resources efficiently.

The relationship between sunflower seed yield/blackgram seed yield/sunflower equivalent yield and the rates of sulphur was studied with the help of regression analysis. A quadratic equation Y= a + bx +cx^2, where, Y is the seed yield (q/ha); x is the rate of sulphur (S) fertilizer applied (kg/ha) was fitted in the regression equation (Tables 4 and 5). Based on sunflower seed yield, the optimum dose of S was worked out to be 53.35 and 53.28 kg/ha in 2006 and 2007, respectively, (Table 4). The mean optimum dose based on two seasons was 56.32 and 43.9 kg/ha, respectively. The response of sulphur in terms of sunflower equivalent was also quadratic and the mean optimum dose was 55.69 kg S/ha. The sunflower being an exhaustive crop required more S than blackgram as was reflected in the optimum dose of this nutrient for these two crops. At the optimum dose of S, the response was 3.14 and 3.97 q/ha giving a net profit of Rs. 3900.4 and Rs. 5223.8 in 2006 and 2007, respectively. The net returns per rupee spent on S fertilizer worked out to be Rs. 3.44 in 2006 and Rs. 4.7 in 2007.

The optimum dose of sulphur for blackgram was to be 43.17 and 44.67 kg/ha in 2006 and 2007, respectively, Table 4. At the optimum dose of sulphur, the response was 0.82 and 0.86 q/ha fetching a net profit of Rs. 1,063.4 and Rs. 1,137.2 in 2006 and 2007, respectively. The return per rupee spent on S fertilizer was computed to be Rs. 1.16 and 1.21 in 2006 and 2007, respectively.

Based on sulphur equivalent yield, the optimum dose of S was worked out to be 55.83

and 55.54 kg/ha in 2006 and 2007, respectively, Table 5. At the optimum dose of S, the response was 4.52 and 5.40 q/ha giving a net profit of Rs 6048.1and Rs 7467.2 in 2006 and 2007, respectively.

The net returns of Rs. 1116.8/ha and B:C ratio of Rs. 1.11, respectively. Intercropping of sunflower with blackgram in 1:3 row ratios recorded the lowest net returns of Rs 6622/ha and B:C ratio (0.78). Amongst S levels, the highest net returns was obtained with 60 kg S / ha (Rs. 9261.0) which was higher by Rs. 3726.7, Rs. 1892.0 and 320.64 than that of recorded at 0, 20, and 40 kg S/ha, respectively. The B:C ratio was highest (0.99) at 60 kg S/ha followed by 40 kg S/ha (0.97) Table 6.

The response of sunflower, blackgram and sunflower equivalent to sulphur was quadratic in nature. The average economic optimum dose of sulphur was 56.4, 43.6 and 56.0 kg S/ha for sunflower, blackgram and sunflower equivalent yield, respectively. The gross and net returns

Table 3. Land equivalent ratio (LER) and competition functions in different planting patterns of sunflower and blackgram intercropping (mean of 2 years)

Treatments		SF 60 +BG (1:1)	SF 90 +BG (1:2)	SF 120 +BG (1:3)	SF 40/80 +BG (2:3)
Land equivalent ratio		01.210	01.190	01.110	01.380
RCC	Kab (Sunflower)	29.880	01.490	00.490	10.480
	Kba (Blackgram)	00.290	00.380	00.350	00.540
Product of RCC (K)		28.500	02.390	01.590	13.730
Competitive ratio	CRa (Sunflower)	04.333	03.509	03.615	03.172
	CRb (Blackgram)	00.231	00.286	00.277	00.315
Aggressivity	Aab (Sunflower)	+0.757	+0.542	+0.439	+0.322
	Aba (Blackgram)	-0.757	-0.542	-0.439	-0.322
	Aba (Blackgram)	-0.757	-0.542	-0.439	-0.322

Table 4. Response of sunflower and blackgram to sulphur and economics (mean of 2 years)

S. No.	Particulars	Sunflower		Blackgram	
		2006	2007	2006	2007
1.	Response	Quadratic	Quadratic	Quadratic	Quadratic
2.	Response equation	Y=9.337+0.1046x-0.000856x2		Y=9.337+0.1046x-0.000856x2	
3.	Optimum economic	0053.35	0053.28	0043.17	0044.67
4.	Yield at optimum dose (q/ha)	0012.48	0016.37	0003.02	0004.07
5.	Responce at optimum dose (q/ha)	0003.14	0003.97	0000.82	0000.86
6.	Response in kg/kg S at optimum dose	0005.89	0007.45	0001.91	0001.94
7.	Profit at optimum	3900.40	5223.80	1063.40	1137.20
8.	Return (Rs) on each	0003.44	0004.62	0001.16	0001.21

Table 5. Response of sunflower equivalent yield to sulphur and economics (mean of 2 years)

S. No.	Particulars	Years	
		2006	2007
1.	Response	Quadratic	Quadratic
2.	Response equation	Y=9.337+0.1046x-0.000856x2	Y=9.337+0.1046x-0.000856x2
3.	Optimum economic dose (kg/ha)	0055.83	0055.54
4.	Yield at optimum dose (q/ha)	0014.57	0019.19
5.	Responce at optimum dose (q/ha)	0004.52	0005.40
6.	Response in kg/kg S	0008.09	0009.72
7.	Profit at optimum	6048.06	7467.19
8.	Return (Rs) on each rupee invested on S	0005.11	0006.34

Table 6. Economics of crop production as influenced by planting patterns and sulphur levels.

Treatments	Cost of cultivation (Rs /ha)	Gross returns (Rs /ha)	Net returns (Rs /ha)	B: C ratio
Planting pattern				
Sole SF	9127.0	18308.60	09181.60	1.00
Sole SF 60+BG (1:1)	9431.0	19900.00	10469.00	1.11
Sole SF 90+BG (1:2)	9020.0	17296.70	08276.70	0.91
Sole SF 120+BG (1:3)	8424.0	15046.90	06622.90	0.78
Sole SF 40/80+BG (2:3)	9581.0	20746.80	11165.80	1.16
Sole BG	7355.0	08146.30	00791.30	0.11
Sulphur (kg/ha)				
0	8568.0	14002.40	05434.40	0.61
20	8738.0	16107.00	07369.00	0.81
40	8908.0	17848.40	08940.40	0.97
60	9078.0	18339.04	09261.04	0.99

comparable to 40 kg S/ha, were higher with application of 60 kg S/ha. The B: C ratio was highest with application of 60 kg S/ha. The B: C ratio was highest with application of 40 kg S/ha. Consequently, the optimum economic dose of sulphur computed for sunflower and blackgram intercropping was 56.0 kg/ha.

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Impact of irrigation levels and mulching on yield and nutrient uptake of okra cultivars under various planting geometry

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ABSTRACT

A field experiment was conducted during rainy season (2009), at College of Agriculture, Bikaner to find out the effect of crop geometry on growth, yield and nutrient uptake of okra (*Abelmoschus esculentus* L. Moench) cultivars under different irrigation levels and mulching. Results indicated that irrespective of irrigation levels, cultivars and mulches higher growth attributes, pod yield/ plant (127 g) and N,P,K uptake (87.5, 15.1, 94.1, respectively) were recorded under wider spacing (75 cm x 40 cm) except, the pod yield/ha (15.9 t/ha) which was higher under closer spacing (40 cm x 20 cm). The growth attributes of okra viz., plant height, leaves/plant, branches/plant and dry weight of leaves were recorded significantly higher at 1.0 V of drip irrigation. However, 0.6 V of drip irrigation recorded significantly highest biomass accumulation, pod yield/plant, pod yield/ha (18.5 and 16.5 t/ha at 40 cm x 20 cm and 75 cm x 40 cm spacing, respectively) and N, P and K uptake of okra. Among cultivars, 'Tulsi' registered significantly higher growth, yield and N, P and K uptake. Among mulches organic mulch produced significantly maximum growth attributes, pod yield/ha (17.4 and 15.6 t/ha at 40 cm x 20 cm and 75 cm x 40 cm spacing, respectively) and uptake of N, P and K over mulches.

Key words : Cultivars, drip irrigation, mulches, okra, planting geometry, yield.

Okra (*Abelmoschus esculentus* L. Moench) is widely grown in tropics and subtropics and it is one of the most important vegetable crops of India. The improvement in productivity of okra can be achieved by use of high yielding cultivars and improved cultural practices best suited to an agro-climatic region. In areas of water scarcity, drip irrigation is one of the most efficient methods of irrigation, which saves up to 80% water along with increase in yield up to 60%. Besides, in order to mitigate the adverse effect of water stress, *in-situ* moisture conservation through mulches is one of the common practices to reduce evaporative losses of water and prolonging moisture availability. Plant spacing also plays an important role in growth and yield of okra. Wide spacing maximize the utilization of sunlight, space, water and nutrients and also decreases insect and disease incidence while, closer spacing of plants may lead to competition among the plants for essential resources. There is a positive relationship between plant population and crop yield (Weiner, 1990).The pod yield per unit area of okra could be increased at closer spacing but individual pod weight and length were higher at wider spacing (Singh, 1990). Therefore, the present investigation was undertaken to find out the effect of wider and closer plant spacing on growth and yield of okra cultivars under different irrigation levels and mulching.

MATERIALS AND METHODS

A field experiment was conducted on okra (*Abelmoschus esculentus* L. Moench) during the rainy season of 2009 at Research Farm, College of Agriculture, Swami Keshwanand Rajasthan Agricultural University, Bikaner (28° 01' N, 73° 22' E and 234.7 m above mean sea level). The climate of this zone is typical arid having deep, saline desert soils with low water holding capacity. Total rainfall received during the crop season was 268.8 mm. The soil of the field was loamy sand, low in organic carbon (0.3%), available N (77.84 kg/ha), available P (9.65 kg/ha) and medium in available K (185.20 kg/ha) and had *p*H 8.2, electrical conductivity 0.2 dS/m with field capacity of 7.4% and permanent wilting point 5.0%.

The experiment was laid out in split-split plot design and replicated thrice with four levels of irrigation viz. 100%, 80% and 60% ET through drip and 100 % recommended surface irrigation equivalent to 1.0, 0.8 and 0.6 volume (V) of surface irrigation as main plots; two cultivars viz., 'Tulsi' and 'Arka Anamika' as sub plots; and three mulching treatments viz., no mulch, organic mulch (Aerva persica @ 10 t/ha) and black polyethylene (25 micron) in sub-sub plots. The seeds were sown at two different plant spacing i.e. 40 cm x 20 cm and 75 cm x 40 cm row to row and plant to plant spacing. After germination of seeds, organic mulch (*Aerva persica*)-a desert weed locally known as bui; was placed in the experimental plots while, black polythene was placed between the rows of okra. In drip irrigation, water was applied daily while in surface method; water was applied at weekly interval. At the time of field preparation FYM @ 200 t/ha was applied. A uniform dose of 60 kg P_2O_5/ha through DAP, 50 kg K_2O/ha through MOP and half dose of nitrogen (50 kg) through urea were applied in the soil at the time of sowing. However, the remaining dose (50 kg) of nitrogen was applied through drip in 5 equal splits at 10 days interval in the form of urea.

The observations on various traits *viz.*, plant height, leaves/plant, branches/ plant, dry weight of leaves, plant biomass and pod yield/plant and pod yield/ha were recorded as per standard method. N, P and K content in plant material was estimated through standard laboratory procedures of colorimetric method (Snell and Snell, 1939), vanadomolybdo phosphoric acid yellow colour method (Jackson, 1967) and flame photometer (Richards, 1954), respectively and uptake was calculated on the basis of nutrient content in plant biomass. Data generated were subjected to analysis of variance (ANOVA) and Critical Difference (CD) at 5% probability level was obtained.

RESULTS AND DISCUSSION

Growth attributes

Growth attributes of okra *viz.*, plant height, leaves/plant, branches/plant, dry weight of leaves and crop biomass accumulation were significantly influenced by irrigation levels, cultivars and mulches (Table 1). The significantly highest values of growth attributes viz., plant height (77.1 cm and 84.5 cm), leaves/plant (42.3 and 47.4) branches/plant (5.5 and 6.1), and dry weight of leaves (1.41 g and 1.55 g) at 40 cm x 20 cm and 75 cm x 40 cm spacing, respectively were recorded at 1.0 V of drip irrigation over remaining irrigation levels. Since, sufficient soil moisture for progressive plant growth was maintained through drip irrigation, it tends to better development of photosynthetic area and accelerated photosynthetic rate by maintaining high soil metric potential in the rhizosphere to reduce plant water stress (Al-Harbhi *et al.* 2008). However, biomass accumulation (8031.1 and 8869.3 kg/ha at 40 cm x 20 cm and 75 cm x 40 cm spacing, respectively) was significantly higher under 0.6 V of drip which may be due to optimum moisture in the entire root zone of the crop which resulted in better physiological activities of plants and finally increased the dry weight.

Compared to 'Arka Anamika'; 'Tulsi' recorded significantly higher growth attributes viz., leaves/plant (38.5 and 43.4), branches/plant (5.2 and 6.1) and biomass accumulation (73111.9 and 8078.6 kg/ha) at 40 cm x 20 cm and 75 cm x 40 cm spacing, respectively, except plant height which found higher in 'Arka Anamika'. As growth and development of a cultivar is the outcome of genomic, environmental and agronomic interactions. Since, both the cultivars were grown under identical management practices and environmental conditions; the observed variation in overall growth of 'Tulsi' could be ascribed to its higher genetic potential, which might have facilitated larger canopy development.

Application of organic mulch recorded a significantly high plant height (73.1 cm and 79.6

Table 1. Effect of irrigation volumes, cultivars and mulches on growth attributes of okra at 60 DAS

Treatment	Pod yield/ plant (g)		Pod yield (t/ha)		N uptake (kg/ha)		P uptake (kg/ha)		K uptake (kg/ha)	
	40 cm x 20 cm	75 cm x 40 cm	40 cm x 20 cm	75 cm x 40 cm	40 cm x 20 cm	75 cm x 40 cm	40 cm x 20 cm	75 cm x 40 cm	40 cm x 20 cm	75 cm x 40 cm
Irrigation levels										
Surface (1.0 V)	63.00	69.40	29.80	36.10	3.10	3.70	1.12	1.22	5572.7	6267.2
Drip (1.0 V)	77.10	84.50	42.30	47.40	5.50	6.10	1.41	1.55	6494.6	7216.6
Drip (0.8 V)	75.10	82.80	41.80	46.70	5.20	5.50	1.40	1.53	7770.7	8496.2
Drip (0.6 V)	66.20	72.80	33.50	38.60	4.10	4.60	1.28	1.44	8031.1	8869.3
SEm±	1.01	1.21	0.81	0.71	0.22	0.27	0.04	0.05	170.23	164.31
C.D. (P=0.05)	3.50	4.20	2.80	2.40	0.70	0.90	0.14	0.19	589.1	568.5
Cultivars										
'Arka Anamika'	80.10	87.50	35.20	41.10	3.70	3.80	1.29	1.43	6622.6	7346.6
'Tulsi'	60.70	67.20	38.50	43.40	5.20	6.10	1.31	1.44	7311.9	8078.6
SEm±	0.36	0.42	0.38	0.67	0.15	0.14	0.02	0.01	39.10	66.40
C.D. (P=0.05)	1.10	1.30	1.20	2.10	0.50	0.40	NS	NS	127.5	216.5
Mulching										
No mulch	66.40	74.60	34.80	39.60	3.20	4.30	1.21	1.31	6532.6	7325.4
Black polyethylene	70.30	77.80	37.20	42.20	4.50	4.90	1.26	1.41	7012.7	7697.8
Organic mulch	73.10	79.60	38.70	44.70	5.70	5.80	1.43	1.58	7356.5	8113.5
SEm±	0.23	0.29	0.44	0.33	0.20	0.17	0.02	0.02	37.13	56.6
C.D. (P=0.05)	0.70	0.80	1.20	0.90	0.50	0.50	0.05	0.06	106.9	163.3

cm), leaves/plant (38.7 and 44.7), branches/plant (5.78 and 5.82), dry weight of leaves (1.43 g and 1.58 g) and biomass accumulation (7356.5 and 8113.5 kg/ha) at 40 cm x 20 cm and 75 cm x 40 cm spacing, respectively as compared to black polyethylene and no mulch. This may be due to higher moisture conservation under organic mulch which provides the favourable climate for soil microbial activity that resulted in better crop growth. This finding is in agreement with the work of Singh *et al.* (1976) in bottle gourd.

Higher values of growth characters were recorded in wider spacing (75 cm x 40 cm) over closer spacing (40 cm x 20 cm). Closer spacing among the plants resulted in lower growth attributes due to the competition for nutrients, moisture, CO_2 etc. and consequently low accumulation of plant food material. These results are in close conformity to Mujeeb-ur-Rahaman *et al.* (2007).

Yield

Different irrigation levels, cultivars and mulches under both the crop geometries led to significant improvement in pod yield of okra (Table 2). The yield parameters viz., pod yield/plant (145.9 g and 168.4 g) and pod yield/ha (18.5 and 16.5 t/ha) at 40 cm x 20 cm and 75 cm x 40 cm, respectively) were recorded highest at 0.6 V of drip irrigation. It is a result of higher irrigation efficiency of drip irrigation method which can fulfill the requirement of plants with comparatively less application of water providing control over excessive vegetative growth during crop development stage. This was also due to better utilization of water and easy uptake of nutrients by plants and excellent soil-air-water relationship with higher oxygen concentration in the root zone. Similar findings were also observed by Singh and Kumar (2007).

Due to high yield potential, pod yield/plant (142.59 and 163.69 g) and pod yield/ha (18.8 and 17.0. t/ha) at 40 cm x 20 cm and 75 cm x 40 cm spacing, respectively were recorded higher in 'Tulsi' over 'Arka Anamika'. The yield attributes viz., pod yield/plant (135.1 and 157.1 g) and pod yield/ha (17.4 and 15.6 t/ha) at 40 cm x 20 cm and 75 cm x 40 cm spacing, respectively were significantly higher with organic mulch than no mulch and black polyethylene mulch. This may be due to appropriate moisture and temperature of the soil, better regulated under organic mulch.

Due to accommodation of maximum number of plants, pod yield/ha was higher in closer spacing than wider spacing whereas, pod yield/plant was higher in wider spacing over closer spacing. Plants grown at wider spacing received comparatively more nutrients and light for their growth and development and thereby, produced more yield/plant. These results are in close conformity with Hossain *et al.,* (2001).

Nutrient uptake

Uptake of N, P and K was also influenced significantly under different irrigation levels, cultivars and mulches under both the crop geometries (Table 2). The highest uptake of N (93.1 and 102.8 kg/ha), P (14.4 and 17.9 kg/ha) and K (97.5 and 109.4 kg/ha) at 40 cm x 20 cm and 75 cm x 40 cm spacing, respectively was recorded at 0.6 V of drip irrigation. Since, nutrient uptake by the crop depends primarily on dry matter accumulation and secondarily on nutrient concentration at cellular level. The increased photosynthetic efficiency under 0.6 V of drip resulted in more dry matter accumulation consequently higher uptake of nutrients. Similar results were also reported by Das *et al.* (2002).

Due to increase in dry matter production, higher uptake of N (83.9 and 92.1 kg/ha), P (13.2 and 16.1 kg/ha) and K (87.8 and 98.2 kg/ha) at 40 cm x 20 cm and 75 cm x 40 cm spacing, respectively was registered in 'Tulsi' than 'Arka Anamika'. The uptake of N (84.5 and 92.6 kg/ha), P (13.7 and 16.1 kg/ha) and K (89.1 and 100.1 kg/ha) at 40 cm x 20 cm and 75 cm x 40 cm spacing, respectively was significantly higher with organic mulch than no mulch and black polyethylene. The higher concentration of nutrients and higher biomass accumulation in plants grown under organic mulch might be attributed to higher nutrient uptake. Similar results were also observed by Batchelor et al. (1996). Similarly, due to higher biomass accumulation, wider spacing recorded higher N, P and K uptake over closer spacing.

Based on the results obtained it may be inferred that wider spacing (75 cm x 40 cm) in

Table 2. Effect of irrigation volumes, cultivars and mulches on pod yield and total N P K uptake (pod + plant biomass) by the okra

Treatment	Pod yield/ plant (g)		Pod yield (t/ha)		N uptake (kg/ha)		P uptake (kg/ha)		K uptake (kg/ha)	
	40 cm x 20 cm	75 cm x 40 cm	40 cm x 20 cm	75 cm x 40 cm	40 cm x 20 cm	75 cm x 40 cm	40 cm x 20 cm	75 cm x 40 cm	40 cm x 20 cm	75 cm x 40 cm
Irrigation levels										
Surface (1.0 V)	103.80	123.70	12.40	10.60	62.50	69.60	9.50	11.70	66.20	74.90
Drip (1.0 V)	120.40	138.70	15.70	14.00	73.50	80.90	11.70	14.20	77.50	86.70
Drip (0.8 V)	138.10	158.20	17.20	15.40	89.10	96.60	14.20	16.50	94.60	104.50
Drip (0.6 V)	145.90	168.40	18.50	16.50	93.10	102.80	14.40	17.90	97.50	109.40
SEm±	1.63	1.25	0.22	0.06	2.57	3.18	0.46	0.35	2.426	2.36
C.D. (P=0.05)	5.60	4.30	0.70	0.20	8.90	11.10	1.60	1.20	8.30	8.10
Cultivars										
'Arka Anamika'	111.60	131.10	13.20	11.30	75.10	83.10	11.80	14.10	80.30	89.50
'Tulsi'	142.50	163.40	18.70	17.00	83.90	92.20	13.20	16.10	87.80	98.20
SEm±	0.54	0.68	0.16	0.09	0.61	1.03	0.38	0.25	1.06	0.92
C.D. (P=0.05)	1.70	2.20	0.50	0.30	1.90	3.30	1.20	0.80	3.40	3.00
Mulching										
No mulch	119.80	138.50	14.70	12.80	73.90	82.90	11.30	13.70	78.10	88.50
Black polyethylene	127.00	146.60	15.80	14.10	80.10	86.90	12.40	15.50	84.40	93.20
Organic mulch	135.10	157.10	17.40	15.60	84.50	92.60	13.70	16.20	89.10	100.30
SEm±	0.86	1.03	0.13	0.11	0.58	0.71	0.31	0.19	1.09	0.97
C.D. (P=0.05)	2.50	2.90	0.40	0.30	1.60	2.05	0.90	0.50	3.10	2.70

okra proved superior in growth and nutrient uptake but pod yield was higher under closer spacing (40 cm x 20 cm). Overall, the cultivar 'Tulsi' grown under organic mulch supplying 0.6 V of drip irrigation registered higher growth, yield and nutrient uptake of okra.

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Response of irrigation and fertigation scheduling on flowering, physiological parameters and fruit yield of guava (*Psidium guajava* L.) under high density planting

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Abstract

An experiment was conducted during 2009-10 and 2010-11 to assess the effect of irrigation and fertigation scheduling on flowering, physiological parameters and fruit yield of 3-years-old guava cv. 'Shweta' planted at the spacing of 2x1m. The experiment was laid out in factorial randomized block design with sixteen treatment combinations, which included four irrigation levels (basin, 50%, 75% and 100% irrigation of IW/CPE) along with four fertigation levels, viz. basal dose, 50%, 75% and 100% water soluble fertilizers and replicated thrice. From the two years pooled observations it was found that 75% irrigation of IW/CPE (I_2) through drip resulted in significantly higher number of flowers per shoot (32.02), fruit set (45.88%), fruit retention (47.83%) and fruit yield of (29.33 t/ha), carbon assimilation rate (5.03 μ mol m^{-2} s^{-1}) and total chlorophyll content (2.39 mg g^{-1} fresh weight) in leaf. However, I_2 and I_3 (100% irrigation of IW/CPE) were at par with each other. Similarly, fertigation level F_2 (45, 20, 20 g NPK water soluble fertilizers) showed significantly higher fruit set (44.93%), fruit retention (47.39%), carbon assimilation rate (4.98 μ mol m^{-2} s^{-1}), total chlorophyll content (2.38 mg g^{-1} fresh weight), fruit yield (5.96 kg $plant^{-1}$ & 29.81 t ha^{-1}). Further interaction of irrigation and fertigation levels I_3F_3, I_3F_2 and I_2F_3 and I_2F_2 were at par with each other and I_2F_2 level (75% irrigation of IW/CPE + 75% WSF) produced significantly higher fruit set (48.85%) and fruit yield (6.56 kg/ plant & 32.79 t/ha).

Key words : Guava, irrigation, fertigation, high density planting, yield.

High density planting of guava is one of the important techniques where higher numbers of plant per unit area are accommodated as compared to the conventional planting density. Basin irrigation is the conventional method widely used to irrigate most of the fruit crops grown in Rajasthan. Many researchers have reported the higher application efficiency of drip irrigation systems over the conventional basin irrigation systems (Salvin *et al.* 2000; Bharambe, *et al.* 2001; Agrawal and Agrawal, 2007) compared to drip and basin irrigation systems in fruits and found that there was savings of 40 to 60% more irrigation water than basin irrigation methods. Singh *et al.* (2006) reported that irrigation requirement met through drip irrigation gave the highest yield of guava (37.70 t/ha) with 164% greater yield as compared to basin irrigation. Fertigation enables adequate supplies of water and nutrients with precise timing and uniform distribution to meet the crop nutrient demand.

Guava is an important fruit crop grown in almost all parts of India and is one of the most preferred fruit crops in Southern Rajasthan. Due to lack of information on irrigation management techniques, the average yield of the crop in Southern Rajasthan is very low because of either excess or deficit soil moisture. The crop is generally grown with basin irrigation, which has low application efficiency. Also, not much information on seasonal water requirements of guava by drip irrigation is available. Keeping this in view the present experiment was carried out to study the response of irrigation and fertigation scheduling on flowering, physiological parameters and fruit yield of guava cv. Shweta under high density planting.

MATERIALS AND METHODS

The experiment was conducted during 2009-10 and 2010-11, on uniform 3-years-old Shweta guava plants planted at the spacing of 2 m x 1m at Horticulture Farm of the Rajasthan College of Agriculture, MPUAT, Udaipur. The region falls under agro climatic Zone IV A (Sub-humid Southern Plain and Aravali Hills) of Rajasthan. There were 4 levels of irrigation, namely basin irrigation (I_0), 50% irrigation of IW/CPE (I_1), 75% irrigation of IW/CPE (I_2) and 100% irrigation of IW/CPE (I_3) and 4 levels of fertigation viz., F_0 (basal dose of 60, 20, 40g NPK plant-1year-1), F_1 (30, 10, 10 g NPK plant-1year-1WSF), F_2 (45, 20, 20 g NPK plant-1year-1WSF) and F_3 (60, 30, 30 g NPK plant-1year-1WSF) total 16 treatment combinations. The experiment was laid out in factorial randomized block design with 3 replications and 2 plants were kept in each treatment. The irrigation was applied to guava plants as per treatments. The basin irrigation system was scheduled on the basis of climatological approach with an IW/CPE ratio of 0.8 and drip irrigation was scheduled as suggested by Mane *et al.* (2006). The drip irrigation was supplied at one day interval while, basin irrigation at 7 days interval. The daily USDA class A open Pan evaporation readings were obtained from meteorological observatory, Agronomy farm of Rajasthan College of Agriculture, Udaipur. As per the treatments water soluble fertilizer grade (NPK-19:19:19) were applied in 5 splits from fruit set to maturity stage and remaining nitrogen was supplemented through urea. The basal dose (F_0) of phosphorus and potassium were fully applied by ring method in the month of July, while nitrogen was applied in 2 split doses, one with basal dose in July and another after fruit setting in October through ring basin at 30 cm away from stem. The plants were pruned twice a year in the months of February and September regularly for canopy management.

Flowering parameters i.e., number of flowers shoot^{-1}, per cent fruit set and per cent fruit retention were recorded by selecting five branches randomly from all directions of the plant and average was calculated during both the years. C-assimilation rate (µ mol m^{-2}s^{-1}) was measured between 10 AM to 12 Noon by CIRAS-2 Portable photosynthesis system under natural radiation and total chlorophyll (mg g^{-1} fw) contents of leaf was estimated by the method as suggested by Arnon (1947). Mature fruits were harvested periodically from each treatment separately and the weight was recorded with the help of single pan balance and expressed in kilogram. Further, fruits/ha were calculated by multiplying the fruit yield/plant to the number of plants/ha (*i.e.*, 5000 plants/ha).

RESULTS AND DISCUSSION

Flowering characteristics of Mrig Bahar

Among different irrigation levels I_2 (75 % irrigation of IW/CPE) produced significantly higher number of flowers shoot^{-1} (32.02), fruit set (45.88%) and fruit retention (47.83%) as compared to basin irrigation I_0 (25.81 and 39.06%, respectively). Under fertigation levels significantly higher fruit set (44.43%) and fruit retention (47.39%) were recorded in F2 (45, 20, 20 g plant^{-1} NPK) whereas, minimum number of flowers shoot^{-1} (26.57) was produced in F_1 (30, 10, 10 g NPK) while, minimum fruit set (39.80%) and fruit retention (44.05%) was found in basal dose (F_0). Further, interaction of irrigation and fertigation resulted maximum fruit set in I_3F_3 (100% irrigation of IW/CPE + 60, 30, 30 g NPK) i.e., 51.05% closely followed by I_2F_3 (50.92%) and I_2F_2 (48.85 %) as compared to minimum in IOF0 (basin irrigation+ basal dose of fertilizers) i.e., 37.43%. However, interaction effect of irrigation and fertigation levels were non-significant for number of flowers shoot^{-1} and fruit retention per cent.

Application of drip irrigation during experimentation effectively increased flowering characters over basin irrigation and the favourable influence on flowering of the plant might be due to the constant supply of water to the plant. This maintains the soil moisture at optimum level eliminating water stress to the plant resulting in greater flowering and fruit set. The results of the present investigation are in close conformity with the findings of Lawand and Patil (1994) in pomegranate and Chauhan *et al.* (2005) in apple.

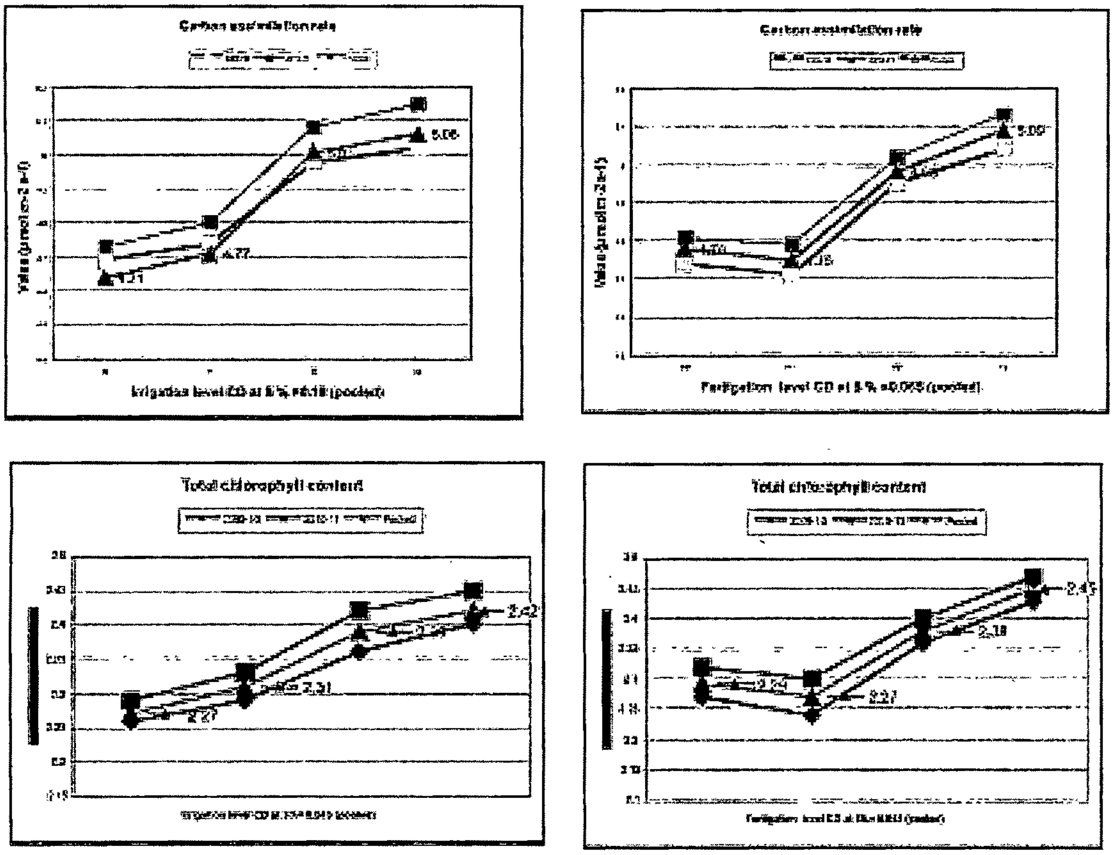

Fig. 1. Effect of irrigation and fertigation levels on carbon assimilation (µmol m^{-2} s^{-1}) and total chlorophyll content (mg g^{-1} fresh weight) in guava

Among various fertigation levels F_2 level (45, 20, 20 g NPK $plant^{-1}$) showed better flowering characters of the plant. It might be due to prolonged availability of nutrients during the growth, flowering and fruiting period from fertigation over basal application which might have improved the fruit set and retention. Similar results have also been reported by Shanker *et al.*, (2002) in guava. Combined interaction of drip irrigation and fertigation level I_3F_3 registered maximum fruit set closely followed by I_2F_3, I_3F_2 and I_2F_2. This might be due to ensure constant supply of water and nutrients, favours better growth and development of the plants.

Physiological parameter

The different irrigation levels significantly affected carbon assimilation rate. Maximum carbon assimilation rate (5.08 µ mol $m^{-2}s^{-1}$) was noticed in I_3 (100 % irrigation of IW/CPE) which was at par with I_2 (5.03 µ mol m^{-2} s^{-1}) as compared to basin irrigation (4.71 µ mol m^{-2} s^{-1}). Further, under fertigation levels maximum carbon assimilation rate (5.09 µ mol m^{-2} s^{-1}) recorded in F_3 (60, 30, 30 g NPK) as compared to minimum (4.75 µ mol m^{-2} s^{-1}) in F_1 (30, 10, 10 g NPK). Interaction of irrigation and fertigation was found non-significant.

Maximum total chlorophyll content was obtained in I_3 (2.42 mg g^{-1} fresh weight) as compared to basin irrigation (2.27 mg g^{-1} fresh weight), while at par with I_2. Similarly, maximum total chlorophyll content under fertigation levels was noticed in F_3 (60, 30, 30 g NPK) i.e., 2.45 mg g^{-1} fresh weight as compared to minimum in F_1 (2.27 mg g^{-1} fresh weight) (Fig. 1). The productivity of any crop depends on the process of photosynthesis, which in turn depends on the chlorophyll content of leaves in plants. Drip irrigation at frequent intervals provides a

Table 1. Effect of irrigation and fertigation levels and their interaction on number of flowers, fruit set, fruit retention and carbon assimilation rate of guava

Treatment	No. of flowers shoot^{-1}	Fruit set (%)	Fruit retention (%)	Carbon assimilation rate (μ mol m^{-2} s^{-1})
I_0	25.81	39.06	43.70	4.71
I_1	28.55	41.36	45.09	4.77
I_2	32.02	45.88	47.83	5.03
I_3	32.82	46.13	47.32	5.08
SEm ±	0.678	0.604	0.619	0.065
C.D. (P=0.5)	1.917	1.709	1.751	0.183
F_0	27.60	39.80	44.05	4.78
F_1	26.57	41.21	44.71	4.75
F_2	30.98	44.93	47.39	4.98
F_3	34.05	46.5	47.78	5.09
SEm ±	0.678	0.604	0.619	0.065
C.D. (P=0.5)	1.917	1.709	1.751	0.183
I_0F_0	23.17	37.43	42.17	4.62
I_0F_1	21.83	38.00	42.55	4.60
I_0F_2	28.20	39.84	44.80	4.78
I_0F_3	30.05	40.98	45.27	4.84
I_1F_0	25.67	39.72	42.83	4.66
I_1F_1	23.82	40.66	43.53	4.64
I_1F_2	30.87	42.01	46.67	4.87
I_1F_3	33.87	43.06	47.32	4.91
I_2F_0	30.67	40.82	45.83	4.87
I_2F_1	30.22	42.92	46.51	4.85
I_2F_2	32.03	48.85	49.43	5.14
I_2F_3	35.18	50.92	49.55	5.27
I_3F_0	30.92	41.22	45.38	4.95
I_3F_1	30.43	43.27	46.25	4.92
I_3F_2	32.83	49.00	48.67	5.15
I_3F_3	37.08	51.05	48.98	5.32
SEm +	1.356	1.208	1.238	0.129
C.D. (P=0.5)	NS	3.418	NS	NS

I_0 (basin irrigation), $I_1$50% irrigation of IW/CPE, $I_2$75% irrigation of IW/CPE, $I_3$100% irrigation of IW/CPE, F_0 60, 20, 40 g NPK/plant/year (basal dose), F_1 30, 10, 10 g NPK/plant/year, F_2 45, 20, 20 g NPK/plant/year, F_3 60, 30, 30 g NPK/plant/year.

consistent moisture regime in the soil and therefore, roots remain active for a longer period over basin irrigation. The findings are in favour by Patil and Patil (2001) they reported that leaf chlorophyll content increased with increasing water supply in guava and highest with the application of IW/CPE = 1. This was also observed by Singh *et al.* (2007) that the full dose of NPK through fertigation gave maximum chlorophyll 'a' (0.51 mg g^{-1} tissue), 'b' (0.40 mg g^{-1} tissue) and total chlorophyll (0.92 mg g^{-1} tissue), while minimum chlorophyll content was found under full dose of NPK applied through soil in 3 year old spur type apple cv. Red Chief.

Fruit yield

Among various levels of irrigation maximum number of fruits per plant was obtained in I_1 (50% irrigation of IW/CPE) while, maximum yield (29.33 t/ha) was in I_2 (75% irrigation of IW/CPE). Under, fertigation levels maximum number of fruits per plant was obtained in F_1 (30, 10, 10 g NPK WSF) while, maximum yield (30.04 t/ha) was in F_3 (60, 30, 30 g NPK) which was at par

Table 2. Effect of irrigation and fertigation levels and their interaction on total chlorophyll content, number of fruits plant^{-1}, yield plant^{-1} and ha^{-1} of guava

Treatment	Total chlorophyll content (mg g^{-1} fresh weight)	Number of fruits plant^{-1}	Yield (kg/plant)	Yield (tonnes/ha)
I_0	2.27	35.42	5.29	26.47
I_1	2.31	37.98	5.21	26.05
I_2	2.39	36.25	5.87	29.33
I_3	2.42	35.13	5.82	29.09
SEm ±	0.016	0.506	0.077	0.384
C.D. (P=0.5)	0.045	1.431	0.217	1.086
F_0	2.29	34.17	5.12	25.60
F_1	2.27	37.63	5.10	25.49
F_2	2.38	36.54	5.96	29.81
F_3	2.45	36.44	6.01	30.04
SEm ±	0.016	0.506	0.077	0.384
C.D. (P=0.5)	0.045	1.431	0.217	1.086
I_0F_0	2.19	33.83	5.08	25.41
I_0F_1	2.16	37.17	5.05	25.24
I_0F_2	2.33	35.17	5.48	27.39
I_0F_3	2.42	35.50	5.57	27.83
I_1F_0	2.24	36.83	5.00	25.00
I_1F_1	2.21	38.00	5.09	25.44
I_1F_2	2.36	38.50	5.41	27.04
I_1F_3	2.42	38.58	5.34	26.71
I_2F_0	2.35	33.83	5.22	26.09
I_2F_1	2.32	38.00	5.16	25.81
I_2F_2	2.41	36.83	6.56	32.79
I_2F_3	2.48	36.33	6.53	32.64
I_3F_0	2.40	32.17	5.18	25.88
I_3F_1	2.38	37.33	5.10	25.49
I_3F_2	2.42	35.67	6.40	32.01
I_3F_3	2.50	35.33	6.59	32.97
SEm ±	0.032	1.012	0.154	0.768
C.D. (P=0.5)	NS	NS	0.434	2.172

(29.81 t/ha) with F_2 (45, 20, 20 g NPK). Further, interaction of irrigation and fertigation resulted maximum fruit yield (32.97 t/ha) in I_3F_3 (100% irrigation of IW/CPE + 60, 30, 30 g NPK) followed by in I_2F_2 (32.79 t/ha) as and minimum (25.00 t/ha) in I_1F_0 (50% irrigation of IW/CPE + basal dose) (Table 2). The results are in conformity with the findings of Patil and Patil (1999) they observed that guava fruit yield was highest (226.31 kg tree^{-1}) when irrigated at an IW: CPE ratio of 0.8 and Singh *et al.* (2007a) revealed a 164 per cent greater yield in case of drip (VD) as compared to that of ring basin irrigation (VRB) in guava. The treatment drip (VD) showed the highest (37.70 t ha^{-1}) yield and lowest yield (14.90 t ha^{-1}) was observed in ring basin (VRB) irrigation method. Similarly, Singh *et al.* (2005) in papaya and Sharma *et al.* (2011) in guava also reported similar findings. Thus, 75% irrigation of IW/CPE (I_2) at alternate day with supplementation of water soluble fertilizers @45, 20, 20 g NPK plant^{-1} year^{-1} (F_2) gave higher yield of guava cv. Shweta under high density planting system.

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Performance of rice variety P 1460 in front line demonstrations under rainfed conditions in Southern humid region of Rajasthan

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ABSTRACT

The study was conducted at Krishi Vigyan Kendra, Banswara in Southern Humid Agro-climatic Zone of Rajasthan (Zone IV b) for three consecutive rainy seasons of 2009, 2010 and 2011 to evaluate the performance of basmati type rice variety "Pusa 1460" at farmers field under rainfed conditions. Front line demonstrations (FLDs) were conducted with scientific package of practices of rice technology. The Pusa 1460 variety of rice was found superior over farmers' existing practices with local landraces. Pusa 1460 with improved production technologies followed in FLDs, increased mean grain yield by 28.7% over existing farmers' practice with only Rs. 1511/ha extra expenditure on inputs. The mean extension gap (0.57 t/ha) and mean IBCR (3.94) are sufficiently high to motivate farmers for adoption of Pusa 1460 and rice production technology.

Key words : Front line demonstration, extension gap, technology gap, technology index.

Rice is the staple food of more than 60% of the world's population. In India, rice occupies about 42.6 m ha of area with total production 95.3 m t (GoI, 2012). The area under rice is fluctuated from year to year depending upon rainfall. The total area is 1.28 lakh ha with the productivity of 2031 kg/ha. The main reason for very low productivity is dependency on rains in major rice growing in area the state. The success of this croplargely depends upon timely sowing and well distributed rains in growing season. Rice production constitutes the major economic activity of tribal farmers in low laying regions of Southern Rajasthan where growing rice during the *Kharif* season is a physio-graphic compulsion.

The major causes of low productivity of rice in the region includes drought, lodging, weeds, insects, pests, diseases, prevalence of local varieties, unavailability of quality seeds of improved varieties in time and non-adoption of recommended production and plant protection technology. The local varieties such as Kalikuamod and Kalazira have some aromatic fragrance, therefore, non-aromatic varieties are unable to replace these varieties. So it is important to demonstrate the high yielding aromatic rice varieties to increase production of rice among the tribal farmers. Recognizing the importance of rice, seed production programme was taken at KVK Banswara district. KVK further spread the rice varieties through frontline demonstrations in the district to boost up the production of rice.

A wide gap exists in the available techniques and its actual application by the farmers which reflected through poor yield in the farmers' field. Farmers are generally practicing old age seedlings and imbalance use of fertilizers. Thus, there is tremendous opportunity for increasing the production and productivity of rice by adopting the improved production technologies. A range of rice production technologies have been generated by agricultural universities and research stations, but the productivity of rice is still low due to poor transfer of technologies from the research farms to the farmers' fields. Very little new knowledge percolates to the farmers' field, hence a vast gap has been observed between knowledge production and knowledge utilization. Front Line Demonstrations (FLD) on rice including recently released early maturing, aromatic, high yielding, fine seeded, disease resistant varieties with INM, IWM and IPM on farmers' field may be helpful. Pusa 1460 is Basmati type aromatic semi-dwarf rice variety which is resistant against bacterial leaf blight and having strong aroma, less chalky grain and fine seeds. It has flowering duration 103 days so it can be taken under rainfed conditions in low lying areas. Hence, KVK has conducted FLDs on rice under rainfed condition in Banswara district of Rajasthan during three consecutive Kharif seasons of 2009 to 2011 with the aim: (i) to evaluate the performance of high yielding aromatic rice variety with recommended package of practices and (ii) to correct and analyse feedback information for further improvement in research and extension programme.

MATERIALS AND METHODS

The study was conducted in Banswara district of Southern Humid Region of Rajasthan by the Krishi Vigyan Kendra to popularize the rice variety "Pusa 1460" with improved production techniques. The constraints in production were identified through participatory approach, farmers meetings, training programmes and field diagnostic visits during crop growth period. Low yield of rice was conceived due to lack of suitable variety of rice, imbalance use of fertilizers, old age seedling, drought, infestation of weeds and improper crop geometry. Based on the farmers problems identified, conducted 125 front line demonstrations under rainfed farming situations during *Kharif* season of 2009 to 2011 at farmers' field. Soil samples were collected and analysed for major plant nutrients. The soils of the region are generally light black to red loam in texture, low in available N & P and medium in available K. The area under each demonstration was 0.4 ha. The crop received rainfall 616 mm, 536 mm and 974 mm during crop growth period in 2009, 2010 and 2011, respectively. To manage assessed problems, improved Basmati type "Pusa 1460" variety seed of rice and zinc sulphate were provided to the farmers as critical inputs and scientific recommended technologies were followed as intervention during the course of front line demonstration programme. The nursery raising was done during onset of monsoon in the last week of June and first week of July of each year. The rice seedlings of 25-30 days old were transplanted in the fields during last week of July and beginning of August every year. The demonstrations on farmers' fields were regularly monitored by the scientists of Krishi Vigyan Kendra from nursery raising to harvesting. In case of local check (control plots), existing farmers' practices were followed by the farmers. Well before conducting the demonstrations, a training programme was organized for the selected farmers of the respective villages each year to impart the technological knowledge of rice production techniques. All other steps like site selection, layout of demonstrations, farmers' participation etc. were followed as suggested by Choudhary (1999). The grain yield of demonstrations as well as farmers' practice (local check) were recorded and analysed according to different parameters suggested by Yadav *et al.* (2004). The details of these parameters are as:

1. Extension Gap = Demonstration yield (D1) - Farmers' practice yield (F1)
2. Technology Gap = Potential yield (P1) - Demonstration yield (D1)
3. Technology Index =

$$\frac{\text{Potential yield (P1) - Demostration yield (D1)}}{\text{Potential yield (P1)}} \times 100$$

4. Additional Return = Demonstration return (Dr) - Farmers' practice return (Fr)
5. Effective Gain = Additional return (Ar) - Additional cost (Ac)
6. Increment B:C ratio = $\dfrac{\text{Additional return } (A_r)}{\text{Additional cost } (A_c)}$

RESULTS AND DISCUSSION

Rainfall pattern and initial crop stand

Nursery raising of crop was satisfactory except in 2010 following good pre-monsoon shower (30.9 and 37.5 mm in 2009 and 2011, respectively) ensuring better seedling growth and timely transplantation in the field. The total rainfall received during the growing seasons was 616, 535 and 974 mm in 2009, 2010 and 2011, respectively. Only *kharif* season of 2011 had normal rainfall (over 850 mm). However its distribution pattern was erratic across the cropping season (June-November) in all three years. The maximum rain 77 to 89% occurred during July to August every year (Fig. 1). September 2009 and June 2010 received the lowest rainfall while in 2011, October and November rainfall did not recieve that resulted in prolonged drought during flowering and grain filling stage of paddy and yield was lowest in 2011.

Since second fortnight of July, water started accumulating in the field and slowly increased in depth and remains 3 to 5 cm in low lying field throughout the end of August in all three years. In this way initial crop growth got momentum with adequate water availability encouraging elongation in plant height and tillering of seedlings. While in October and November of year 2009 and 2010 crop received good rainfall which resulted higher grain yield than kharif 2011. Boonjung and Fukai (1996) also reported that the effect of water stress on rice yield was most severe when drought occurred during panicle development and anthesis resulting low yield due to less number of spikelets per panicle and filled grains.

Grain yield

Grain yield of rice was higher under demonstrations as compared to existing farmers' practice. The increase in grain yield under demonstrations was 14.9 to 43.2% (Table 1) over existing farmers' practice. On an average 28.7% yield advantage was recorded under front line demonstrations carried out with improved seed and scientific package of practice as compared to farmers' traditional way of rice cultivation.

Gap analysis

An extension gap of 0.26 to 0.95 t/ha in yield was found between demonstrated technology and farmers' practices during different years. Average extension gap was 0.57 t/ha. The extension gap was lowest (0.26 t/ha) during 2011 which was due to prolonged drought at the time of grain fillings while the highest extension gap (0.95 t/ha) was during 2009 which may be due to well distribution of rainfall in which Pusa 1460 performed better and gave maximum yield (3.15 t/ha). Over all such gap might be attributed due to improved seed of Pusa 1460 and adoption of improved production technology in the demonstrations which resulted in higher grain yield than the existing farmers' practices. Wide technology gaps were observed during all the years. The mean technology gap of total 125 front line demonstrations was found 2.5 t/ha which is 50% of potential yield. The wide

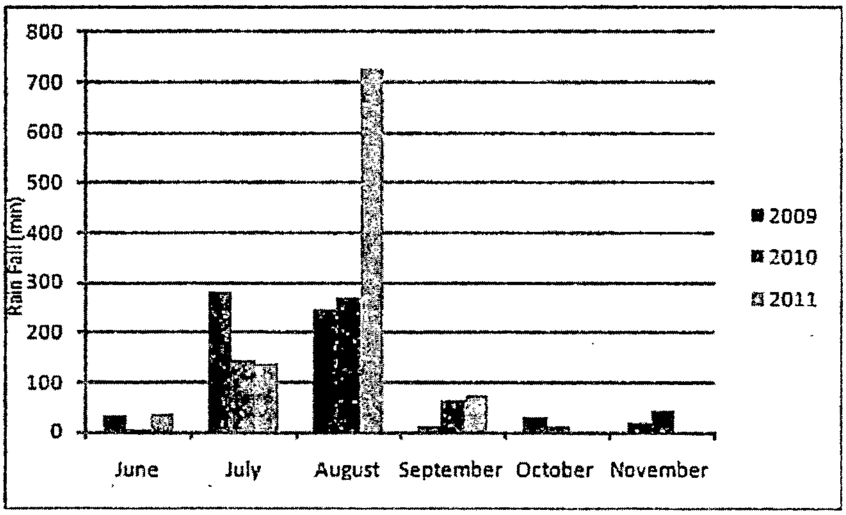

Fig. 1. Rainfall distribution pattern across the months of growing season from 2009 to 2011

Table 1. Grain yield and gap analysis of paddy under front line demonstrations at farmers' field

Season/ Year	No. of demonstrations.	Potential yield (t/ha)	Demonstration yield (t/ha)	Farmers' practice Yield (t/ha)	Increase over Farmers' practices (%)	Extension gap (t/ha)	Technology gap (t/ha)	Technology index (%)
Kharif 2009	50	5.0	3.15	2.20	43.2	0.95	1.85	37.0
Kharif 2010	50	5.0	2.35	1.85	27.0	0.50	2.65	53.0
Kharif 2011	25	5.0	2.01	1.75	14.9	0.26	2.99	60.0
Average	42	5.0	2.50	1.87	28.4	0.57	2.50	50.0

Table 2. Economic analysis of front line demonstrations on paddy var. P 1460 at farmers' field

Season/ Year	Cost of cash input		Additional cost in demons. (Rs./ha)	Sale price (MSP) of grain (Rs./ha)	Total Returns (Rs/ha)		Additional cost in demons. (Rs./ha)	Effective gain (Rs./ha)	Incremental B:C ratio (IBCR)
	Demons. (Rs./ha)	Farmers' practice (Rs./ha)			Demons. (Rs./ha)	Farmers' practice (Rs./ha)			
Kharif 2009	3,731	2,300	1,431	980	30,870	21,560	9,310	7,,879	6.50
Kharif 2010	3,731	2,300	1,431	1,030	24,205	19,055	5,150	3,719	3.60
Kharif 2011	4,619	2,950	1,669	1,110	22,311	19,425	2,886	1,217	1.73
Average	4,027	2,516	1,511	1,040	25,795	20,013	5,782	4,272	3.94

differences in technology gap during different years might be due to rainfall distribution. Similarly the technology index for all the demonstrations during different years was in accordance with technology gap. Higher technology index reflected the inadequate proves of technology for transferring to farmers and insufficient extensions services for transfer of technology.

Economic analysis

Seed and fertilizers were considered as critical cash inputs for the demonstrations as well as farmers' practices. On an average, an additional investment of Rs. 1511/ha was made under demonstrations. Economic returns as a function of grain yield and minimum support price (MSP) as sale price varied during different years. Maximum returns were obtained during the year 2009 followed by 2010 due to higher grain yield. The higher additional returns and effective gain obtained under demonstrations could be due to improved variety Pusa 1460 and adoption of scientific production techniques like timely transplanting and application of fertilizers. The highest incremental benefit: cost ratio (6.50) and effective gain (Rs. 7879/ha) were observed during 2009 which is due to higher additional return and low additional cost (Table 2). Sarda and Khurana (1993), Singh et.al (2009) and Nirmala and Muthuraman (2009) also found that adoption of scientific techniques by farmers in rice production results higher economic returns.

CONCLUSION

Improved Basmati type variety "Pusa 1460" of paddy and production technologies followed in demonstrations, on an average increased the grain yield by 28.7% over existing farmers' practice. The increment in yield cost only Rs. 1511/ha. This amount is so less that even small and marginal farmers can afford it. The mean extension gap (0.57 t/ha) and IBCR (3.94) are sufficiently high to motivate the farmers for adoption of Pusa 1460.

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Effect of different organic sources on productivity and quality of pearlmillet (*Pennisetum glaucum*) and their residual effect on wheat (*Triticum aetivum*)

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ABSTRACT

A field experiment was conducted during 2004-05 and 2005-06 at Indian Agricultural Research Institute, New Delhi to study the effect of different organic sources of nutrients on productivity and quality of pearlmillet (*Pennisetum glaucum* L. R. Br. Emend Stuntz) and to study the residual effect of various treatments on succeeding crop of wheat (*Triticum aetivum* L.). The experiment comprised eight treatments viz. control, Biofertilizer (*Azospirillum* + PSB), FYM (10 t/ha) + biofertilizer (*Azospirillum* + PSB), Vermicompost (10 t/ha) + biofertilizer (*Azospirillum* + PSB), Sesbania leaf manuring + biofertilizer (*Azospirillum* + PSB), FYM (10 t/ha) + legume intercropping, Vermicompost (10 t/ha) + legume intercropping and Sesbania leaf manuring + legume intercropping. Different organic sources showed considerable increase in growth components, yield and quality of pearlmillet. Vermicompost (10 t/ha) + biofertilizer produced the highest pearlmillet grain yield, that is 2.18 and 2.04 t/ha during 2004 and 2005 respectively; and had maximum residual effect on wheat yield.

Key words : Biofertilizer, FYM, intercropping, organic sources, pearlmillet, sesbania leaf manuring, vermicompost, wheat.

Pearlmillet [*Pennisetum glaucum* (L.) R. Br. Emend Stuntz] is most preferred crop of dryland and rainfed area owing to its drought escaping mechanism coupled with comparatively higher production ability under low soil fertility, soil moisture deficit and intense heat. Pearlmillet-wheat is an important cropping system in north-western dry tract of India and it plays significant role in food and nutritional security of the country. To sustain long term productivity of this cropping system without any environmental threat, use of organic sources of nutrients is important (Choudhary, 2005). Kumar and Gautam (2004) reported increase in grain yield and dry matter of pearlmillet due to application of organics. Low cost nutrient sources involving organic manures and biofertilizers can be affordable by resource poor farmers of rainfed areas and hence, can become a better substitute for expensive and unsustainable inorganic fertilizers. The application of organic sources of nutrients not only supplies all essential nutrients but also facilitates the growth and development of beneficial microbes, assists better uptake of nutrients by crop plants and counteracts the harmful effect of agrochemicals. Moreover, use of organics also helps in improving water holding capacity of soil, allows better root growth and leaves residual effect on soil fertility for long period, thus organics are important tool of sustainable farming. Since information on nutrient management in pearlmillet-wheat system through organic sources is meagre, the present investigation is carried out to know the effect of different organic sources of nutrients on growth, yield and quality of rainfed crop of pearlmillet and to study the residual effect of various organics on succeeding wheat.

MATERIALS AND METHODS

A field experiment was conducted during 2004-05 and 2005-06 at the Agronomy Farm, Indian Agricultural Research Institute, New Delhi to study the response of pearlmillet to different organic sources of nutrients and to study the their residual effect on succeeding wheat.

The soil was sandy clay loam in texture having 58.2% sand, 14.2% silt, 27.7% clay with field capacity of 19.12% and permanent wilting point of 6.52%,. The available N, P, and organic carbon content in the soil were 254 kg/ha, 9.89 kg/ha, and 0.33% respectively. The soil was nearly neutral in reaction having pH 7.2.

The experiment comprised of eight treatments viz. control, biofertilizer (azospirillum + PSB), farm yard manure (FYM) @ 10 t/ha + biofertilizer (azospirillum + PSB), vermicompost (VC) @ 10 t/ha + biofertilizer (azospirillum + PSB), Sesbania leaf manuring (SLM) + biofertilizer (azospirillum + PSB), FYM @ 10 t/ha + legume intercropping (LIC), vermicompost @ 10 t/ha + legume intercropping and Sesbania leaf manuring + legume intercropping; which were tested under Randomized Block Design in three replications with plot size 5m X 3m. The pearlmillet variety 'Pusa Composite 383' was sown with using a seed rate of 4 kg/ha with the above sited treatments under rainfed condition; whereas, succeeding wheat (variety 'HD- 2687') was grown on residual fertility under limited irrigation conditions.

Vermicompost (containing 1.2% N) was applied to pearlmillet as broadcast as per treatment and incorporated manually. Green leaves of Sesbania (containing 0.4% N on green weight basis), after cutting into small pieces buried into the soil at last ploughing. Cowpea was grown as legume intercrop in pearlmillet as paired row arrangement of 30/70 cm. The pearlmillet crop was sown after a pre sowing irrigation in the year 2004 which was followed by one life saving irrigation at flowering stage due to late onset of monsoon and long dry spell in between the season, whereas, in 2005 no irrigation was applied to the pearlmillet. Two irrigations, first at crown root initiation and second at flowering stage, were applied to wheat during both the years of study.

RESULTS AND DISCUSSION

Pearlmillet

Growth parameters

Number of tillers/ meter row length, dry matter accumulation and days to 50% flowering increased markedly due to different organic sources of nutrients (Table 1). Use of FYM + biofertilizer, vermicompost + biofertilizer, FYM + legume intercropping and Sesbania leaf manuring + legume intercropping influenced all the growth parameters significantly over control. However, maximum number of tillers/ meter row length, dry matter accumulation and days to 50% flowering, were observed with vermicompost + biofertilizer. Superiority of vermicompost + biofertilizer treatment is contributed by vermicompost application enriching the supply of all the essential macro and micronutrients higher than other organic sources and secondly, the use of vermicompost had incorporated some earthworms in the field which could have worked in the soil and helped in improving the physical conditions of the soil thus increasing aeration for root development and more availability of nutrients, as also reported by Robinson et al. (1992). The vermicompost enhanced soil physical, chemical and biological properties and thus overall vegetative growth of the crop. This enhanced growth of pearlmillet was also attributed by the increased availability of nitrogen and phosphorus to the pearlmillet plant due to the use of Azospirillum and PSB, where Azospirillum bacteria fixes atmospheric nitrogen and PSB increases solubility of native phosphorus of the soil in the rhizosphere of pearlmillet (Mekki et al. 1999). In addition of increased nutrient availability, Azospirillum and PSB also affected the plant growth through the production of growth hormones like IAA, GA and Cytokinin (Sattar and Gaur, 1987).

Yield

Remarkable improvement in number of earheads/ meter row length and earhead length was observed due to different organic sources of nutrients (Table 2). Maximum number of earheads and earhead length were recorded with vermicompost + biofertilizer. It was at par with all other sources except sesbania leaf manuring + legume intercropping. Being a genetic character, 1000-grain weight was not affected significantly by different organic sources of nutrients (Table 2). The superiority these organics might be due to increased

Table 1. Effect of different organic sources of nutrients on no. of tillers per meter row length, dry matter accumulation and days to 50% flowering of pearlmillet

Treatments	No. of tillers/ m row length		Dry matter accumulation (g/plant)		Days to 50% flowering	
	2004	2005	2004	2005	2004	2005
Control	21.3	17.3	38.42	39.79	42.0	43.0
Biofertilizers	28.3	23.3	54.21	54.11	45.6	44.6
FYM + Biofertilizer	28.3	24.6	58.00	58.63	48.0	48.0
VC + Biofertilizer	28.6	25.0	65.66	64.09	50.0	50.0
SLM + Biofertilizer	28.0	24.0	56.09	55.50	43.3	44.6
FYM + legume intercropping	29.0	23.6	56.70	56.36	46.0	45.0
VC + legume intercropping	29.6	24.3	55.08	56.62	46.6	46.3
SLM + legume intercropping	27.3	22.0	40.33	41.98	43.3	42.6
SEm	0.47	1.01	3.97	3.93	1.40	1.43
C.D. (P=0.05)	1.43	3.07	12.04	11.93	4.27	4.35

Table 2. Effect of different organic sources of nutrients on yield attributing characters, pearlmillet equivalent yield and net returns

Treatments	Earheads/m row length		Earhead length (cm)		1000-grain weight (g)		Grain yield (t/ha)		Stover yield (t/ha)	
	2004	2005	2004	2005	2004	2005	2004	2005	2004	2005
Control	17.0	16.3	23.6	23.3	6.20	6.26	1.40	1.37	5.33	4.87
Biofertilizers	23.0	22.3	27.0	26.5	6.22	6.33	1.66	1.65	6.55	6.13
FYM + Biofertilizers	23.3	23.0	31.0	29.4	6.40	6.43	2.04	1.94	6.88	6.50
VC + Biofertilizers	23.9	23.7	31.2	30.4	6.40	6.46	2.18	2.04	7.10	6.72
SLM + Biofertilizers	22.4	22.0	28.0	27.6	6.38	6.34	1.82	1.76	6.21	5.75
FYM + LIC	22.9	23.3	28.9	28.5	6.38	6.36	1.86	1.85	6.66	6.20
VC + LIC	22.8	23.3	29.5	29.0	6.36	6.40	1.93	1.89	6.66	6.15
SLM + LIC	21.7	20.7	26.0	25.6	6.30	6.27	1.55	1.56	6.55	6.03
SEm	0.87	0.85	1.17	1.16	0.56	0.59	0.059	0.116	0.212	0.216
C.D. (P=0.05)	2.63	2.58	3.62	3.50	NS	NS	0.179	0.351	0.643	0.656

photosynthetic activity resulted in higher accumulation of photosynthates. Further, these have translocated to sink due to better development of source-sink channel. Grain and stover yield of pearlmillet increased markedly due to different organic sources of nutrient, Chaudhary and Gautam (2007) also found the similar results. Maximum grain and stover yield, however, was recorded with vermicompost + biofertilizer. The yield of any species is the cumulative function of yield attributes; the effect of any treatment on these parameters ultimately affects the biological and economical yield of crop.

Quality

The variation in N content in grain was found significant due to application of different organic sources of nutrients, except biofertilizer and Sesbania leaf manuring + legume intercropping treatment (Table 3). Accordingly, the variation in protein content in pearlmillet grain was found significant due to different organic sources of nutrients except biofertilizer

Table 3. Effect of different organic sources of nutrients on nitrogen and protein content in pearlmillet grain

Treatments	Nitrogen contents (%)		Protein content (%)	
	2004	2005	2004	2005
Control	1.58	1.61	9.88	10.05
Biofertilizers	1.69	1.70	10.56	10.60
FYM +Biofertilizer	1.86	1.85	11.62	11.55
Vermicompost + Biofertilizer	1.92	1.92	12.00	11.89
SLM + Biofertilizer	1.81	1.78	11.31	11.12
FYM + legume intercropping	1.82	1.80	11.37	11.24
Vermicompost + legume intercropping	1.84	1.82	11.50	11.36
SLM + legume intercropping	1.69	1.68	10.56	10.49
SEm	0.04	0.04	0.25	0.24
C.D. (P=0.05)	0.13	0.12	0.78	0.74

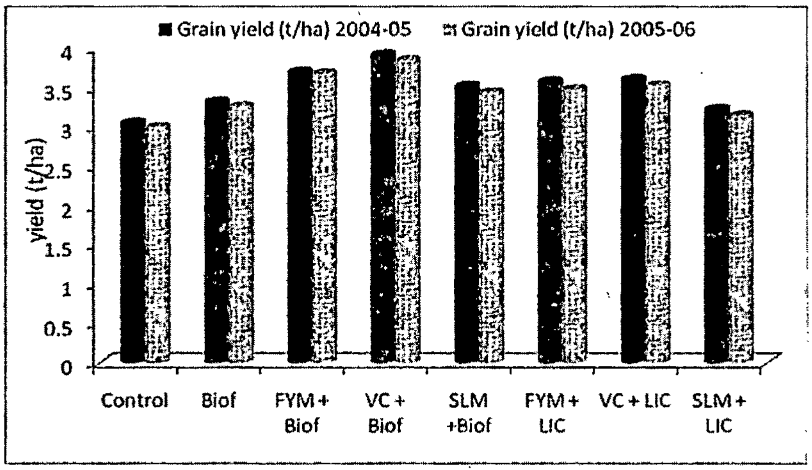

Fig. 1. Wheat yield as influenced by different organic sources of nutrients applied to preceding crop of pearlmillet

and Sesbania leaf manuring + legume intercropping. The highest protein content in grain was observed with vermicompost + biofertilizer. It was found at par with FYM + biofertilizer, vermicompost + legume intercropping and FYM + legume intercropping.

N is the structural component of protein and thus has a positive correlation with N content in grain. The higher N content in the grain as a result of vermicompost application could be due to its higher N content (1.2 %), and mineralization effect upon native N. The results of present study are in line with the findings of Singh and Yadav (2006-2007). Higher N and protein content in pearlmillet grain with biofertilizer application might be due to more uptake of nutrients through effective root system and increased concentration of nutrients in soil solution. Quality improvement through the use of organic sources might be due to better microbial activity and fixation of atmospheric N. The microbes secrete many growth promoting substances which accelerates the physiological processes like synthesis of carbohydrates and proteins. This result corroborates with the findings of Mekki *et al.* (1999).

Residual effect on wheat

The grain yield of wheat was greatly influenced by treatments applied to preceding crop of pearlmillet. The results are in closer conformity with Choudhary (2005) and

Choudhary and Gautam (2007). The highest grain yield was observed with vermicompost + biofertilizer and it was closely followed by FYM + legume intercropping, FYM + legume intercropping and sesbania leaf manuring + biofertilizer (Fig. 1). In general, organic manure, besides causing overall improvement in the soil health, increased the activity and number of soil microorganism by feeding them. They transform non-available plant nutrients into available form (Yawalkar *et al.* 1992).

It can be concluded that different organic sources of nutrients had remarkable effect on growth, yield and quality of pearlmillet. Application of vermicompost + biofertilizer recorded highest growth and yield, and better quality of pearlmillet. Various organic sources of nutrients applied to pearlmillet had significant residual effect on productivity of succeeding wheat. The maximum wheat yield was recorded with vermicompost (10 t/ha) + biofertilizers, applied to preceding pearlmillet crop.

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Effect of sulphur levels on growth, yield and quality of Indian mustard (*Brassica juncea*) genotypes

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ABSTRACT

A field experiment was conducted during winter season of 2008-09 and 2009-10 on sandy loam soil Bichpuri, Agra to find out the effect of sulphur levels on growth, yield and quality of Indian mustard [*Brassica juncea* (L.), Czernj and Cosson] genotypes. The treatments consisted of four genotypes (Pusa Bold, 'Rohini', 'Varuna' and 'Kranti') of mustard and four levels of sulphur (0, 30, 60 and 90 kg/ha) applied through elemental sulphur in factorial randomized block design replicated thrice. Pusa Bold genotype recorded the highest seed yield of 2.05 and 2.09 t/ha followed by 'Varuna', 'Rohini' and 'Kranti' respectively. Significant response was observed up to 90 kg S/ha in seed and stover yield. Oil content and nutrient uptake were also highest under this treatment. 'Pusa Bold' gave highest net return of Rs. 39575 followed by 'Varuna', 'Rohini' and 'Kranti', respectively. Highest net returns of Rs. 42,018 was recorded with the application of 90 kg S ha. However, net return/Rs. invested (3.35) was higher at 60 Kg S/ha.

Rapeseed-mustard is an important group of oilseed crops in the world. India ranks 2nd in acreage and 3rd in production with contribution of 21.7% and 10.7% to the estimated global area (30.74 million hectares) and production (59.93 million tonnes), respectively during 2009-10 (AICRPRM, 2010). Indian mustard is one of the important oilseed crops grown in India. Due to poor yield, oil seed production in the country does not meet the requirement of growing population. The productivity of mustard can be increased by proper fertilizer management and putting more area under irrigation.

Sulphur is the fourth important nutrient after nitrogen, phosphorus and potassium for Indian agriculture. Sulphur deficiency has been found to occur in soils which are coarse textured and low in organic matter. Sulphur requirements of crop plants is quite high and high yielding varieties require higher amounts of sulphur as compared to low yielding varieties of the crops. About 42.3%, Indian soils and 32.0% U.P. soils are deficient in sulphur. It is well accepted that sulphur deficiency in Indian soils is wide spread and major constraint in the way of increasing crop productivity, produce quality and farm incomes (Tandon 2010). With the introduction of high yielding varieties and increased cropping intensity, large amounts of nutrients are removed from the soil gradually. Oilseed crops have been reported to deplete the soil sulphur relatively to a greater extent. Knowledge of the concentration of plant nutrients in a crop and the amount of nutrients removed by a particular crop from the soil may be a helpful guide for the formulation of a sound fertilizer management programme. In light of these, the present investigation was therefore, undertaken to study the effect of sulphur levels on mustard genotypes.

MATERIALS AND METHODS

The field experiment was conducted during winter season of 2008-09 and 2009-10 at Agricultural Research Farm of Raja Balwant Singh College, Bichpuri, Agra, Uttar Pradesh. The soil was sandy loam with pH 7.8 and 7.8, containing organic carbon 0.34 and 0.35%, available nitrogen 212.0 and 204.5 kg/ha , P 7.80 and 7.50 kg/ha, K 215.2 and 218.4 kg/ha and sulphur 8.1 and 8.8 kg/ha during the first and second year, respectively. There were 16 treatment combinations comprising four genotypes ('Pusa Bold', 'Rohini', 'Varuna' and 'Kranti') and 4 levels of S (0, 30, 60 and 90 kg/ ha) replicated thrice in factorial randomized block design. A half dose of 80 kg N/ ha, 40 kg P_2O_5 /ha and 30 kg K_2O/ha through Urea, DAP and Muriate of potash were applied. Half dose of N and full dose of P and K were applied at sowing. The remaining N was top dressed after the first irrigation. Different doses of sulphur were applied through elemental sulphur before sowing as basal dressing. The crop was sown on 20th October 2008 and 26th October 2009 with seed rate 5 kg /ha. The seed was sown in rows 30 cm apart at depth of 5 cm as per treatments. Data on growth yield and oil content etc were recorded as per standard procedures (A.O.A.C.,1984). The economics of each treatment was also computed as per standard procedures.

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RESULTS AND DISCUSSION

Performance of genotypes

Among the genotypes, 'Varuna' was significantly taller than 'Kranti', 'Pusa Bold' and 'Rohini' at all the growth stages except 30 DAS. Significantly maximum dry weight of accumulation /plant was exhibited in 'Pusa Bold' which was 47.0, 9.8, 19.3 and 9.0 % higher than 'Rohini' at 30, 60, 90 DAS and at harvest stage respectively. However, the cultivar 'Pusa Bold' and 'Varuna' were statistically on par for dry weight at these stages. Significantly the highest number of pods/plant, seeds/pod and 1000 seed weight were recorded in 'Pusa Bold' followed by 'Varuna', 'Rohini' and 'Kranti'. The maximum seed yield of 2.05 and 2.09 t/ ha was produced by cv 'Pusa Bold' during 2008-09 and 2009-10 respectively, which was significantly superior over 'Rohini', 'Varuna' and 'Kranti'. This was due to the fact that 'Pusa Bold' produced better yield attributes viz, plant height, dry weight, number of pods/plant, number of seeds/pod and 1000 seed weight than other genotypes (Table 1). Similar findings were also reported by Arthamwar (1996), Kumar *et al.* (2001) and Sinha *et al.* (2002). The lowest seed yield in 'Kranti' in both the years was due to less number of pods/ plant, number of seeds/pod and 1000 seed weight. In case of stover yield, it is evident from the Table 2 that 'Varuna' produced maximum stover yield (6.00 and 6.08 t/ha) during 2008-09 and 2009-10 respectively, which was significantly higher over rest of genotypes. 'Pusa Bold' produced significantly higher oil content than 'Rohini' and 'Kranti', however, the difference of oil content between 'Pusa Bold' and 'Varuna' was at par. 'Pusa Bold' showed 0.44 and 0.65 % higher oil content than 'Varuna' during the first and second year respectively. According to Singh and Singh (1977), the increase in oil content was mainly due to increase in glucoside formation (allylisothiocynate) and also sulphur as a constituent of multi enzyme complex. 'Varuna' showed maximum total uptake of N, P, K and S (115.5, 28.3, 78.4 and 22.4 kg/ha) which was closely followed by 'Pusa Bold'. However both the genotypes were significantly superior over 'Kranti' and 'Rohini' genotype (Table 2).

Effect of sulphur

Various levels of sulphur significantly influenced the growth and yield attributes *viz.* plant height, dry weight/plant, pods/plant, seeds/pod and 1000 seed weight in both the years. The plant height increased significantly with each increment in the dose of sulphur up to 60 kg/ha. However, the difference in plant height due to further increase in the dose of sulphur was not significant. The rate of increase in plant height was more at 60 kg S/ha, beyond which it declined, perhaps due to better nutritional environment for plant growth at active vegetative stages as a result of improvement in root growth, cell multiplication, elongation and cell expression in the plant body (Steffenson, 1954). Application of 60 kg S/ha produced more dry weight/plant at 90 DAS compared with control and 30 kg S/ha. Better nutrition to plant resulted in more height and number of branches and other growth parameter, which resulted in higher dry weight of plant. These results are in conformity with those reported by and Kumar and Yadav (2007).

The number of pods/plant significantly increased up to 60 kg S/ha. However, the highest number of pods of 374.7/plant was recorded

Table 1. Effect of genotypes and sulphur levels on growth and yield component of Indian mustard (mean of two years)

	Plant height (cm)				Dry weight of plant (g)				No. of pods/plant	No. of seeds/pod	1000 seed weight (g)
Genotype	30DAS	60 DAS	90 DAS	At Harvest	30DAS	60 DAS	90 DAS	At Harvest			
'Pusa Bold'	15.8	132.1	165.4	165.7	2.74	11.33	38.81	84.35	356.0	13.6	5.12
'Rohini'	15.3	127.2	163.4	164.0	1.86	10.31	32.53	77.32	325.4	13.1	4.87
'Varuna'	16.2	138.6	170.0	171.9	2.54	10.80	36.90	83.74	351.2	13.6	5.07
'Kranti'	16.0	141.3	166.9	168.5	2.06	11.86	35.41	78.85	317.9	12.4	4.66
C.D. (P=0.05)	NS	3.7	4.2	4.4	0.35	1.13	3.31	4.58	20.4	0.6	0.16
S-Level (Kg/ha)											
0	14.3	127.0	162.2	162.6	1.67	9.96	26.68	75.32	288.2	10.9	4.61
30	15.6	134.0	165.0	165.5	2.11	10.89	34.75	80.73	324.0	11.8	4.82
60	16.6	138.4	169.2	170.8	2.62	11.40	40.64	84.44	363.6	14.9	5.06
90	16.8	139.8	169.3	171.2	2.79	12.05	41.57	83.78	374.7	15.2	5.25
C.D. (P=0.05)	0.9	3.7	4.2	4.4	0.35	1.13	3.31	4.58	20.4	0.6	0.16

Table 2. Effect of genotypes and sulphur levels on yields , oil content , total uptake and economics of Indian mustard

	Seed Yield (t/ha)		Stover Yield (t/ha)		Oil content (%)		Total Uptake (kg/ha)				Economics (₹/ha)		
Genotype	2008-09	2009-10	2008-09	2009-10	2008-09	2009-10	N	P	K	S	Cost of cultivation	Net returns	Net return/ ₹ invested
'Pusa Bold'	2.05	2.09	5.17	5.95	40.83	41.22	115.2	28.2	75.3	21.1	11884	39575	3.33
'Rohini'	1.88	1.93	5.20	5.40	39.28	40.10	104.0	25.5	68.3	18.0	11404	35125	3.08
'Varuna'	2.02	2.07	6.00	6.08	40.65	40.95	115.5	28.3	78.4	22.4	11827	39148	3.31
'Kranti'	1.80	1.89	5.01	5.25	39.07	39.84	100.4	24.0	65.4	16.5	11231	33470	2.98
C.D. (P=0.05)	0.098	0.095	0.183	0.167	0.47	0.51	4.03	1.09	1.87	0.91	-	Ñ	Ñ
S-Level (Kg/ha)													
0	1.68	1.70	4.28	4.40	37.56	38.08	83.86	19.8	53.91	11.20	10109	30732	3.04
30	1.81	1.85	5.01	5.22	39.28	40.26	98.22	23.8	64.61	15.42	10948	33501	3.06
60	2.11	2.18	6.06	6.29	41.18	41.88	122.2	30.7	81.19	24.06	12261	41076	3.35
90	2.17	2.26	6.57	6.77	41.81	42.12	131.0	31.1	87.92	27.47	12928	42018	3.25
C.D. (P=0.05)	0.098	0.095	0.183	0.167	0.47	0.51	4.03	1.09	1.87	0.91	-	-	-

with 90 kg S/ha. The difference between 60 and 90 kg S/ha was on a par. The highest number of seeds/pod was recorded at 90 kg S/ha, which was on a par with that of 60 kg S/ha, and significantly superior to the control and 30 kg S/ha. The maximum seed weight of 5.25 g/1000 seeds was recorded with 90 kg S/ha, and minimum in the control (4.61 g/1000 seeds). This may be due to large amount of sulphur found in the seed and siliqua, which is considered essential for seed formation and boldness of seeds. There results are also in accordance with those of Kumar and Yadav (2007).

The seed and stover yields and oil content were significantly influenced by different levels of sulphur (Table 2). The highest seed yield of 2.17 and 2.26 t/ha was recorded at 90 kg S/ha during 2008-09 and 2009-10 respectively which was on par with those at 60 kg S/ha and this was significantly superior to the control and 30 kg S/ha during both the years. This may be attributed to the increasing levels of S which resulted in greater accumulation of carbohydrates, protein and their translocation to the productive organs, which in turn improved all the growth and yield attributing characters, resulting more seed yield. The findings confirm the results of Yadav and Sharma (2002) and Sharma *et al.* (2009). However, maximum stover yield was also recorded at 90 kg S/ha which was significantly superior to all the other sources of sulphur treatments. The increase in oil content due to application of 30, 60 and 90 kg S/ha over control was 4.5,9.6 and 11.3% during 2008-09 and 5.7, 9.9 and 10.6% during 2009-10 respectively. The findings confirm the result of Gokhale *et al.* (2005) and Sarangthem *et al.* (2008).

The increasing levels of sulphur significantly increased the uptake of N, P, K and S. The maximum uptake of 131.0 N, 31.1 P, 87.9 K and 27.4 S kg/ha was recorded with the application of 90kg S/ha, which was significantly superior to all other sulphur treatments. The increase in nutrient uptake was mainly due to better nutrition, which resulted in better growth and yield and ultimately in higher uptake of nutrients. Enhanced uptake of N, P, K and S with sulphur application has also been reported by Choudhary *et al.* (2003) and Singh and Singh (2007).

Economics

'Pusa Bold' was more remunerative than 'Varuna'. The increase in the levels of sulphur increased the cost of cultivation up to 90 kg S/ha. The highest net return of Rs. 42,018 was recorded at 90 kg S/ha. Net return/Rs. invested was the highest at 60kg S/ha.

Thus it may be concluded that Indian mustard variety 'Pusa Bold' along with 60 kg S/ha may provide better yield and quality under sandy loam soil of Uttar Pradesh.

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Fertility restoration studies in different cytoplasms of pearl millet [*Pennisetum glaucum* (L.) R. BR.]

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ABSTRACT

Pearl millet [*Pennisetum glaucum* (L.) R. Br.], hybrids grown widely in India are all based on A_1 CMS source. Though alternative sources of CMS are available and found to be highly stable, their utility is restricted due to non-availability of suitable restorers. The present investigation carried out using three different cytoplasms (A_1, A_4 and A_5) as female and A_1 cytoplasm as male showed differential restoration of fertility. The fertility restoration was moderate to partial for both A_4 (16% to 52%) and A_5 (20%) cytoplasms. The male parent PPMI 69 showed complete fertility restoration with ICMA 99555 belonging to A_4 cytoplasm. Identification of restorers for diverse cytoplasmic male sterile sources opens up new avenues in pearl millet hybrid breeding.

Key words: *Pennisetum*, pearl millet, fertility restoration, restorer, maintainer.

Pearl millet [*Pennisetum glaucum* (L.) R. Br.] (2n=14), is a drought tolerant warm season cereal crop grown as staple food grain. It is the major source of feed and fodder on about 25 million hectares in Asia and Africa. It is grown primarily under very hot and dry conditions on infertile soils of low water-holding capacity where other crops fail completely. In India, pearl millet is the fourth most important cereal crop, widely grown by the resource poor farmers in the arid and semiarid regions, particularly in the states of Rajasthan, Maharashtra, Gujarat, Uttar Pradesh and Haryana, which account for nearly 95 percent of the acreage under pearl millet.

Availability of exploitable male sterility system in pearl millet has made it possible to commercially exploit heterosis and hybrid vigour to increase productivity. The discovery of Tift 23A_1, cytoplasmic-nuclear male sterility (CMS) and its successful utilization in breeding male-sterile lines of commercial pearl millet hybrids is a landmark in pearl millet improvement (Athwal,1965; Burton,1965; Burton and Powell, 1968). When hybrids based on Tift 23A_1 cytoplasmic background succumbed to downy mildew infection in 1970s, research efforts were intensified at IARI, New Delhi, several other pearl millet breeding centers and ICRISAT (International Crops Research Institute for Semi-Arid Tropics), Patancheru to diversify the genetic base of male-sterile lines in the A_1 cytoplasmic system and to explore other CMS systems in pearl millet. Burton and Athwal (1967) used A_1, A_2 and A_3 CMS sources for developing hybrids while two other sources (A_v and A_4) derived from different accessions of *P. glaucum* SSP. violaceum = monodii, a wild relative of cultivated pearl millet were identified by Marchais and Pernes (1985) and a totally new and different A_5 cytoplasmic male sterility system was developed by Rai (1995).

The important features that contribute to the commercial viability of any male sterility system are- complete male sterility of A-lines, high levels of male-fertility restoration of their hybrids, stability of these two characteristics across environments, and high frequency of maintainers in a diverse range of breeding materials (Rai *et al.* 2001). Though, different cytoplasmic male sterility systems are available in pearl millet, systematic studies on identification of restorers on these diverse cytoplasms are meager. Amongst those that were evaluated extensively (i.e., A_2 and A_3 systems),

Table 1. Male and Female parents from different cytoplasmic sources

S. No	Cytoplasm	Female parent (Male sterile lines)	Male parent
1.	A_1	MS 5141A, MS 843 A, ICMA 88004, ICMA 89111, ICMA 91444, ICMA 92111, ICMA 93333, ICMA 95111	D-23, PPMI 69, PPMI 493, PPMI 741, PPMI 761
2.	A_4	ICMA 98333, ICMA 99222, ICMA 99555, ICMA 00777, ICMA 04888	
3.	A_5	ICMA 07999	

none performed any better than the A_1 CMS system with respect to one or more of the mentioned features. Though the A_4 and A_5 sources were found to be highly stable, their utility is restricted due to non-availability of suitable restorers (Rai *et al.* 2006). Hence, work in this direction is essential to make use of diverse sterile sources in the development of new Pearl millet hybrids with suitable restorers for further commercial exploitation.

The present investigation was taken up to identify restorers and maintainers for different cytoplasmic backgrounds in pearl millet.

Table 2. Percent seed set and pattern of fertility restoration

% seed set	Type of restoration
> 90	Strong restoration(SR)
80-90	High(HR)
60-80	Moderate(MR)
10-60	Partial(PR)
< 10	Low(LR)
0	Maintainer(M)

MATERIALS AND METHODS

The material comprised of fourteen cytoplasmic male sterile lines belonging to different cytoplasmic sources like A_1 (8), A_4 (5) and A_5 (1) as female parents and five restorers coming from A_1 background as male parents (Table 1). All these parents were crossed in a line x tester mating design in the rainy season of 2009. The hybrids along with their parents were grown in a randomized block design with three replications during rainy season of 2010 and were evaluated for fertility restoring ability to identify restorers and maintainers on A_1, A_4 and A_5 cytoplasm.

The hybrids were grown in three rows of 4 m. length with intra row spacing of 15 cm and inter row spacing of 75 cm in the farm of Division of Genetics in Indian Agricultural Research Institute, New Delhi following the recommended package of practices. The spikes of five plants in each treatment were selfed with parchment paper bag before flowering and the same plants were used for recording seed set per cent. The percentage of seed set was worked out by following the procedure given by Kishan and Borikar (1989) in Table 2.

RESULTS AND DISCUSSION

The data from the selfing studies show the percent seed set in the specific cross combinations involving different cytoplasms with the A_1 male gametes as all the testers belonged to A_1 cytoplasm. The results are presented in the Table 3. The data shows that the seed set values ranged from 0 to >90%. The seed set depends on the aspects like compatibility of the cytoplasm of the female gamete i.e. egg with the nuclear background of the male gamete. As the cytoplasmic background is different in different male sterile lines the variation observed is valid. The reason for extreme variation in the different lines of A_1cytoplasms could be due to differential interaction of the nuclear background of the male gamete with the cytoplasm of the female gamete in the particular line.

The extent of restoration among different cytoplasms is presented in Table 4. Results of fertility restoration reaction of the various lines revealed that - of the 70 hybrids, strong restoration was observed only in two crosses of A_1 cytoplasm (MS 843 A and ICMA 93333 with PPMI 761), high restoration was recorded in

Table 3. Percent seed set observed in different cross combinations involving A_1, A_4 and A_5 cytoplasms of Pearl millet

PARENTS	D 23	PPMI 69	PPMI 493	PPMI 741	PPMI 761
5141A (A_1)	47.5 (PR)	30.5 (PR)	35.1 (PR)	47 (PR)	19.5 (PR)
843A (A_1)	40 (PR)	16 (PR)	37 (PR)	25 (PR)	91 (SR)
ICMA88004 (A_1)	65 (MR)	45 (PR)	67 (MR)	52 (PR)	62 (MR)
ICMA89111 (A_1)	40 (PR)	41 (PR)	27 (PR)	23.5 (PR)	9.5 (LR)
ICMA91444 (A_1)	70 (MR)	0 (M)	27.1 (PR)	0 (M)	0 (M)
ICMA92111 (A_1)	3.7 (LR)	25.8 (PR)	27 (PR)	2.8 (LR)	0 (M)
ICMA93333 (A_1)	87 (HR)	33 (LR)	20 (PR)	68 (MR)	93 (SR)
ICMA95111(A_1)	32 (PR)	36 (PR)	37 (PR)	29 (PR)	29.5 (PR)
ICMA98333 (A_4)	16 (PR)	71.1 (MR)	10.2 (LR)	43.2 (PR)	22.2 (PR)
ICMA99222 (A_4)	66.0 (MR)	30.2 (PR)	6 (LR)	69.2 (MR)	4.9 (LR)
ICMA99555 (A_4)	30.3 (PR)	82 (HR)	22 (PR)	64 (MR)	22 (PR)
ICMA00777 (A_4)	50.5 (PR)	2.9 (LR)	18.5 (PR)	0 (M)	0 (M)
ICMA04888 (A_4)	2.1 (LR)	39.2 (PR)	37.1 (PR)	51 (PR)	56.5 (PR)
ICMA07999 (A_5)	0 (M)	39.2 (PR)	74 (MR)	0 (M)	0 (M)

SR = strong restorer; HR= high restorer; MR= Moderate restorer; PR = Partial restorer, LR- Low restorer and M = Maintainer

Table 4. Variation in extent and type of restoration in different cytoplasms of Pearl millet

Name of the cytoplasm	Strong restoration	High restoration	Moderate restoration	Partial restoration	Low restoration	Maintainer
A_1 cytoplasm	2 (5%)	1 (2.5%)	5 (12.5%)	24 (60%)	4 (10%)	4 (10%)
A_4 cytoplasm	-	1 (4%)	4 (16%)	13 (52%)	5 (20%)	2 (8%)
A_5 cytoplasm	-	-	1 (20%)	1 (20%)	-	3 (60%)
	2 (2.85%)	2 (2.85%)	10 (14.29%)	38 (54.26%)	9 (12.86%)	9 (12.86%)

ICMA 93333 of A_1 cytoplasm with D 23 and ICMA 99555 of A_4 cytoplasm with PPMI 69.

Moderate restoration was observed in 5 crosses of A_1 cytoplasm, 4 crosses of A_4 cytoplasm and one cross of A_5 cytoplasm. Partial restoration was recorded in 24 combinations with A_1 cytoplasm, 13 combinations with A_4 cytoplasm and one combination involving A_5 cytoplasm. Low restoration was observed in 4 crosses involving A_1 cytoplasm and 5 crosses of A_4 cytoplasm. No restoration was observed in 4 crosses of A_1 cytoplasm, 2 crosses of A_4 cytoplasm and three crosses of A_5 cytoplasm. The comparative results indicate that moderate to partial restoration is possible in all the cytoplasms. Among the A_4 and A_5 restoration is more possible in A_4 than in A_5 as the extent of no restoration is only 8% in A_4 as compared to that of 60% in A_5. These results reveal that frequency of restoration on A_4 cytoplasm is quite high compared to A_1 and A_5 indicating the possibility of developing hybrids on A_4 source (Andrews and Rajewski, 1994; Rai, 1995; Rai *et al.* 1998). This may be ascribed to the following reasons like different backgrounds of the female parents into which the A_1 cytoplasm has been introgressed and variable interaction of the nuclear and cytoplasmic organelle genomes i.e. chloroplast and mitochondrial genomes with the nuclear genome.

There were significant differences in the extent of seed set and fertility restoration among different cytoplasms with A_1 testers. This can be explained as the variable interaction of A_1 cytoplasm of the male gamete with the eggs of different cytoplasms namely A_1, A_4 and A_5 i.e. cytoplasmic nuclear interactions. Even among the lines of A_1 cytoplasm with the A_1 testers, large variability is observed in the extent of fertility restoration. The inheritance studies for A_1

cytoplasm restoration conducted by Yadav *et al.* (2010) suggested more likelihood of a single-gene control of male sterility and fertility restoration. However, a 3-gene model of male sterility/fertility restoration where dominant alleles at any two of the three duplicate complimentary loci will lead to male fertility could not be ruled out, nor could be ruled out a 2-gene control with duplicate interaction. There was indication of variability even within a highly inbred R-line for fertility restoration gene(s). In another report by Lakshmana *et al.* (2010) on fertility restoration suggested that the frequency of restoration on A_4 cytoplasm was quite high compared to A_1 and A_5 indicating the possibility of developing hybrids on A_4 source.

CLASSIFICATION OF RESTORATION

The seed set percentage recorded on a hybrid represent the restoring ability of a pollen parent. This seed set percentage can vary from 0 to 95 per cent, thus representing wide range of variation in the restoration ability of pollen parent. In the fertility restoration studies conducted in sorghum, those genotypes showing just above 60 per cent seed set were broadly grouped as restorers and these restorers were classified into different categories based on their restoration ability (Kishan and Borikar, 1989; Biradar, 1995). In the present investigation, five inbreds were evaluated for their restoration ability on fourteen diverse sources of male sterility. The genotypes which could restore fertility up to 80% were categorized as potential restorers, those with restoration of fertility from 10 to 80% were categorized as partial restorers and those below 10% restoration were categorized as maintainers. The different categories of restorers for different male sterile cytoplasmic lines is presented in the following Table 5. It is also observed that the male parents are acting as restorers in one cytoplasmic background and as partial restorer in other cytoplasmic background and as maintainer in another. This clearly shows the impact of nuclear and cytoplasmic interactions which affect the fertility status.

In the present study, it is observed that a single male parent is acting as a complete restorer, partial restorer and a maintainer for different cytoplasms as well as same cytoplasm ex - D 23 and PPMI 761 as shown in Table 5. This shows the possibility of utilization of that particular combination and development of new male sterile lines in the future in different backgrounds. This would certainly reduce the risk associated with the use of single cytoplasmic source in the development of hybrids. On the basis of commonness of restoration on different cytoplasm, it is possible to infer the probable cytoplasmic distance existing between the cytoplasms.

Even among the same cytoplasmic source, the restoration of fertility was not same as observed in the A_4 cytoplasm where PPMI 69 restored fertility in ICMA 95333 while it maintained sterility in ICMA 99111. From the study it was also clear that the frequency of maintainers was high for A_4 cytoplasm compared to A_5 cytoplasm.

Similar studies conducted by Rai *et al.* (2006) at ICRISAT in 2002 revealed that A_4 and A_5 cytoplasms showed stable male sterility. The frequency of maintainers was highest in A_5 compared to A_4 and A_1 and hence provided the greatest opportunities for genetic diversification of A- lines followed by A_4 and then A_1. In a study conducted by Tara Satyavathi *et al.* (2009), desirable effects of earliness and maturity were obtained in hybrids developed using A_4 cytoplasm while desirable heterosis could be obtained for plant height, spike girth, number of nodes, chlorophyll content, relative carotenoids and 1000 grain weight from A_5 cytoplasm. Hence the identification of restorers and maintainers for A_4 and A_5 cytoplasms to develop hybrids opens up new avenues in diversification of cytoplasm for development of hybrids in pearl millet.

CONCLUSION

The present study brings out the restoration capabilities of the five male parents tested against fourteen diverse cytoplasmic male sterile lines of pearl millet. Identification of restorers/ maintainers helps to diversify the genetic background of these lines and it is possible to develop male sterile lines in different genetic backgrounds. It is desirable to have male sterile lines with varying maturity and height levels as

Table 5. Classification of the restoration ability of pearl millet inbreds in different cytoplasmic backgrounds

Male parent	Complete restorer for	Partial restorer for	Maintainer for
D 23	ICMA 93333(A_1)	MS 5141A(A_1) MS 843A(A_1) ICMA 88004(A_1) ICMA 89111(A_1) ICMA 91444(A_1) ICMA 95111 (A_1) ICMA 98333(A_4) ICMA 99222(A_4) ICMA 99555 (A_4) ICMA 00777(A_4)	ICMA 92111(A_1) ICMA 04888(A_4) ICMA 07999(A^5)
PPMI 69	ICMA 99555(A_4)	MS 5141A(A_1) MS 843A(A_1) ICMA 88004(A_1) ICMA 89111(A_1) ICMA 92111(A_1) ICMA 95111(A_1) ICMA 98333(A_4) ICMA 99222(A_4) ICMA 04888(A_4) ICMA 07999(A_5)	ICMA 91444(A_1) ICMA 93333(A_1) ICMA 00777(A4)
PPMI 493	None	MS 5141A(A_1) MS 843A(A_1) ICMA 88004(A_1) ICMA 89111(A_1) ICMA 91444 (A_1) ICMA 92111(A_1) ICMA 93333(A_1) ICMA 95111(A_1) ICMA 99555(A_4) ICMA 00777(A_4) ICMA 04888(A_4) ICMA 07999(A_5)	ICMA 98333(A_4) ICMA 99222(A_4)
PPMI 741	None	MS 5141A(A_1) MS 843A(A_1) ICMA 88004(A_1) ICMA 89111(A_1) ICMA 93333(A_1) ICMA 99222(A_4) ICMA 99555 (A_4) ICMA 04888(A_4)	ICMA 91444(A_1) ICMA 92111(A_1) ICMA 00777(A_4) ICMA 07999(A_5)
PPMI 761	MS 843A (A_1) ICMA 93333(A_1)	MS 5141A(A_1) ICMA 88004(A_1) ICMA 95111(A_1) ICMA 98333(A_4) ICMA 99555(A_4) ICMA 04888(A_4)	ICMA 89111(A_1) ICMA 91444(A_1) ICMA 92111(A_1) ICMA 99222(A_4) ICMA 00777(A_4) ICMA 07999(A5)

it gives scope for selecting restorers with good combining ability and adaptation to diverse agro climatic conditions. It was observed that the male parent D 23 acts as a complete restorer for ICMA 93333 which belongs to A_1 cytoplasm, while it acts as a maintainer for ICMA 92111(A_1), ICMA 04888(A_4) and ICMA 07999(A_5).The other male parent PPMI 69 acts as a complete restorer for ICMA 99555 belonging to A_4 cytoplasm and as maintainer for ICMA 91444 and ICMA 93333 of A_1 cytoplasm along with ICMA 00777 of A_4 cytoplasm. The two male parents PPMI 493 and PPMI 741 could not provide complete restoration to any of the fourteen CMS lines. The male parent PPMI 761 could completely restore fertility in two male sterile lines 843A and ICMA 93333 which belong to A_1 cytoplasm. The present study firstly brings out the possibility of developing successful hybrid combinations in diverse cytoplasmic background other than the routinely used A_1 cytoplasm. Secondly it also brings out the possibility of use of these male parents in the development of male sterile lines in pearl millet.

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Residual effect of vermicompost and thiourea on growth and yield attributes of mustard (*Brassica juncea* L) in semi arid regions of Agra

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ABSTRACT

The field experiment was conducted during winter seasons (*Rabi*) of 2007-08 2008-09 in semiarid regions of Agra district to see the residual effect of vermicompost and thiourea on mustard crop (*Brassica juncea* L). The treatment included four levels of residual vermicompost and seven different levels of residual thiourea in a plot size of 4 x 3 m each with 3 replications. Mustard variety "Pusa Bold" was used. The growth characters of mustard i.e. plant height, no. of primary and secondary branches /plant, no. of siliquae/plant, length of siliqua, no. of seeds/siliquae and test weight showed a significant difference due to vermicompost residue left after the application in the preceding crop up to a dose of 3.0 t/ha. However, with further increase in residual vermicompost level to 4.5 t/ha, no significant difference in growth characters were observed. Similarly the seed and stover yield also increased significantly with increase in residual vermicompost level up to a level of 3.0 t/ ha. A significant difference was also observed in oil content and oil yield up to a residual level of 3.0 t/ha and a maximum of 38.12 % and 743.22 kg/ha in oil content and yield was observed in treatment plots with residual level of 3.0 t/ha. The residual effect of thiourea was found to be non-significant in all treatment levels.

India is one of the major oilseeds producing country in the world, production of which needs to be enhanced to meet the national shortfall as the availability of edible oil in India is about 20 g/day/head against the balanced nutritional requirement of 30 g/day/head (Economic survey, 2004-05). Mustard among the oil seed crop is one of the most important *rabi* season crop and there is a great scope to exploit the potential yield with the use of chemical fertilizers in association with organic manures. Farm yard manure (FYM) is being used mostly as a major source of organic manure in field crops since time immemorial. The significance of FYM incorporation in poor soils has been well established for increasing the productivity (Kumar *et al.*, 1996). Now in recent times due to higher cost and non-availability of FYM in the villages, the importance of other organic manures like vermicompost is increasing in great extent.

Several problems including soil fertility deterioration and environmental pollution are emerging as a result of present agricultural system is affecting soil productivity. Chemical fertilizer along with organic manures can be used in a best way on sandy soils by improving the soil physico-chemical properties and availability of other nutrients for crop plants thus considerably increasing crop yield. The other major problem of inadequate plant stand in semi arid zone (Pearson, 1985) can perhaps be reduced by use of some biostimulants which are known to improve seedling emergence. Thiourea which is initially used to break the dormancy is now known to possess germination stimulating effect (Mayer, 1956). Thiourea is a sulphohydryl compound which contains one -SH group besides nitrogen in the form of -NH2. Agarwal (1971) has observed thiourea application as an effective treatment for improving plant growth and development. Application of thiourea has been reported beneficial in some crops grown in semi-arid regions (Sharma, 1988 and Sahu *et al.* 1993).

Although there is lots of research work carried out to see the effect of organic manure and thiourea directly on the crops but very few studies were undertaken to see their residual effect on the succeeding crop. Thus, the present study was carried out to see the residual effect of vermicompost and thiourea on growth and yield attributes of mustard in semi-arid regions of Agra district.

MATERIALS AND METHODS

The field experiment was conducted for two consecutive years during winter (*Rabi*) seasons of 2007-08 and 2008-09 at agriculture farm of Raja Balwant Singh College of Agriculture, Bichpuri, Agra (272'N latitude and 770.9'E longitude). The experiment was laid out in split plot design keeping four levels of residual vermicompost (0, 1.5, 3.0 and 4.5 t/ha) as a main plot and seven levels of thiourea (0, seed soaking @ 500 ppm, seed soaking @ 1000 ppm, foliar spray @ 500 ppm, foliar spray @ 1000 ppm, seed soaking and foliar spray @ 500 ppm each , seed soaking and foliar spray @ 1000 ppm each) as sub-plots with three replications of each plot with a plot size of 12 m^2. The mustard variety "Pusa Bold" was used as a test crop. The treatment were applied in the preceding pearlmillet crop and its residual effect were being observed in succeeding mustard crop which was sown on 28th September 2007 and 25th September 2008 in the respective years with row to row spacing of 30 cm and plant to plant 10 cm apart. The mustard seed rate was 6 kg/ha.

Physico-chemical properties of experimental plot were found out following standard procedures. The experimental soil was sandy loam in texture, low in organic carbon (0.350%), available N (186 kg/ha), available P (16.5 kg/ha) and medium in available K (296.1 kg/ha). The soil was slightly alkaline in reaction with a pH of 7.6. The recommended dose of P and K were applied prior to sowing during both the years of experimentation. Full dose of vermicompost was applied in the soil prior to sowing of previous crop of pearlmillet during both the years. Half dose of thiourea was applied as a basal dose and remaining half was top dressed at 30 DAS. Seed was soaked for 8 hours in a solution of thiourea @ 500 ppm and 1000 ppm prior to sowing. Two irrigations were given during both the years in mustard crop. Total rains of 18.8 and 157.3 mm were received during 2007 and 2008 during mustard crop seasons respectively.

RESULTS AND DISCUSSION

The growth and yield attributes characters of mustard i.e. plant height, no. of primary and secondary branches/plant, no. of siliquae/plant, length of siliquae, no. of seeds/siliquae and test weight (Table 1) clearly indicates that a significant difference was observed with the vermicompost residue left after the application in the preceding crop. The plant height increased significantly with increase in dose of vermicompost in both years up to a dose of 3.0 t/ha with the pooled maximum height of 166 cm. However, with further increase in vermicompost to 4.5 t/ha, no significant difference in plant height was observed. Thus, was found on pooled basis that plots with residue of vermicompost @ 1.5, 3.0 & 4.5 t/ha showed an increase of 4.8, 14.5 & 14.5% in plant height over the control in which no vermicompost was applied.

It was found on pooled basis that no. of primary and secondary branches (Table 1) per plant increased with increase in residual vermicompost from 1.5 t/ha to 4.5 t/ha. More primary and secondary branches (10.09 & 17.30 respectively) were observed in the plots having residue of vermicompost @ 4.5 t/ha which were at par (9.67 & 16.51) with the plots with vermicompost residue of 3.0 t/ha. Over the control, no of primary and secondary branches were found to increase by 48.4 and 51.0 % respectively.

The yield attributes i.e. no. of siliqua/plant on the main axis also increased significantly with increase in residual vermicompost and were found to be maximum (49.95) in plots with the application of vermicompost @ 4.5 t/ha in the preceding crop. However, no of siliquae/plant was found to be at par (49.76) in the plots in which vermicompost was applied @ 3.0 t/ha in the preceding crop with the plots in which vermicompost was applied @ 4.5 t/ha. The magnitude of increase in siliqua on the main axis in the plots with residual treatment of 3.0 t/ha was 34.91 and 17.50 per cent respectively over the control and residual vermicompost plot of 1.5 t/ha on pooled basis. It was found from the data (Table 1) that the application of vermicompost in the preceding crop showed a significant increase in the length of siliqua in the succeeding mustard crop and the largest siliqua (13.17) cm was found in the treatment plot with vermicompost application of 4.5 t/ha in the preceding crop which was found to be at par (13.12 cm) with the treatment plot with vermicompost application of 3.0 t/ha. On pooled basis, the increase in the length of siliqua in treatment plot of 3.0 t/ha was found to be 34.21 & 17.33 % more over the plots with control and 1.5 t/ha level of vermicompost. Besides length of siliquae, no. of seeds/siliquae in mustard was also found to vary significantly with the increase in level of vermicompost in the preceding crop from 10.52 (control) to 14.35 (4.5 t/ha). However, the no. of seeds/siliquae was found to be at par (14.33) with the vermicompost treatment plots of 3.0 t/ha. The observed significant increase in seed/siliqua under 3.0 t/ha plots was 36.24 and 18.37 % over control and 1.5 t/ha, respectively on pooled basis. When compared the residual effect of vermicompost on the test weight of the mustard, it was found to vary significantly with increase in residual vermicompost from control up to 3.0 t/ha. However, at higher residual level of vermicompost i.e. 4.5 t/ha, it was at par (3.55) with 3.0 t/ha.

The residual effect of thiourea was also studied in the succeeding mustard crop and it was found to be non-significant with different treatments of thiourea in growth and yield attributes. While comparing the seed and stover yield (Table 2), it has been revealed that the residue of vermicompost in the succeeding mustard crop significantly increased the seed and stover yield. The highest seed and stover yield (2.0 & 4.58 t/ha) was observed in the plots in which vermicompost was applied @ 4.5 t/ha which was found to be 30.9 and 31.80 % higher over the control on pooled basis. A non-significant relation was found in the increase in the seed and stover yield when mustard was harvested from the plots in which vermicompost was applied @ 3.0 and 4.5 t/ha in the preceding crop.

Harvest index (%) was also worked out to see the effect of residual vermicompost on the succeeding mustard crop. The harvest index was found to be 30.42% for the plots in which vermicompost was applied @ 3.0 and 4.5 t/ha in the preceding crop as compared to control which was found to be 30.56%. However, a non-significant variation was recorded for the harvest index for both the years.

Besides growth and yield attributes, the effect of residual vermicompost was also seen on the content and yield of oil in the succeeding mustard crop. The data from the Table 2 revealed that the application of various levels of vermicompost in the preceding crop considerably and significantly increased the oil content of succeeding mustard crop during both the years. The highest oil content (38.17%) was found in the plots having residue of vermicompost @ 4.5 t/ha which was found to be at par with the residual treatment of 3.0 t/ha (38.12%). On pooled basis, oil content in residual treatment of vermicompost @ 3.0 t/ha was found to be higher by 6.57 and 3.01% over the control and residual treatment plots of 1.5 t/ha respectively. Also the oil yield was found to be 743.22 kg/ha when the vermicompost was applied @ 3.0 t/ha in the preceding crop, which was found to be higher than 35.64 and 17.47 per cent over the control and 1.5 t/ha residual vermicompost treatments, respectively. This higher yield may be because of sulphur which was found in appropriate quantities in vermicompost and which is found in a readily available form in vermicompost.

The residual effect of thiourea was also found to be non-significant on yield and oil content of mustard when thiourea was applied in the preceding crop. This may be because thiourea is a highly a reactive chemical, though less than pure form of urea, which is consumed or volatilized or leached down during the preceding crop and the residue in the succeeding mustard crop becomes negligible. Also the seed soaking and foliar spray of thiourea treatment in the preceding crop has low persistence in the

Table 1. Residual effect of different doses of vermicompost and thiourea on growth and yield attributes of Mustard (Brassica juncea) for the year 2007-08 and 2008-09

Treatments	Pooled growth parameters (2007-08 and 2008-09)						
	Plant height (cm) at harvest	Primary branches/ plant	Secondary branches/ plant	Siliqua/ plant	Length of siliqua	Seed/ siliqua	Test weight
Vermicompost (t/ha)							
0.0	145.0	6.80	11.46	36.88	9.77	10.52	3.24
1.5	152.0	7.53	12.75	42.34	11.18	12.11	3.32
3.0	166.0	9.67	16.51	49.76	13.12	14.33	3.54
4.5	166.0	10.09	17.30	49.95	13.17	14.35	3.55
SE m ±	2.1	0.405	0.761	1.202	0.409	0.192	0.029
CD (P = 0.05)	6.4	1.248	2.346	3.704	1.509	0.593	0.089
Thiourea							
Control	157.0	8.24	13.94	43.56	11.55	12.61	3.37
Seed soaking @ 500ppm	157.0	8.43	14.40	44.26	11.70	12.68	3.39
Seed soaking @ 1000ppm	157.0	8.55	14.49	44.51	11.71	12.77	3.40
Foliar spray @ 500 ppm	157.0	8.47	14.53	44.82	11.80	12.83	3.41
Foliar spray @ 1000 ppm	157.0	8.64	14.76	45.15	11.93	12.90	3.44
Seed soaking @ 500 ppm + Foliar spray @ 500 ppm	157.0	8.63	14.75	45.41	12.00	12.95	3.45
Seed soaking @ 1000 ppm + Foliar spray @ 1000 ppm	157.0	8.74	14.71	45.42	11.98	13.04	3.45
SE m ±	3.2	0.409	0.729	1.729	0.435	0.515	0.058
CD (P = 0.05)	NS	NS	NS	NS	NS	NS	NS

Table 2. Residual effect of different doses of vermicompost and thiourea on yield and oil per cent of Mustard (Brassica juncea L.)

Treatments	Yield Parameters			Harvest Index	Oil content (%)	Oil yield (Kg/ha)
	Seed	Stover	Biological yield			
Vermicompost						
0.0	15.32	39.78	50.13	30.56	35.77	547.92
1.5	17.10	39.04	56.13	30.45	37.00	632.66
3.0	19.49	44.60	64.10	30.42	38.12	743.22
4.5	20.05	45.88	65.93	30.42	38.17	764.80
SE m ±	0.415	0.976	1.389	0.061	0.231	14.562
CD (P = 0.05)	1.278	3.008	4.280	NS	0.712	44.869
Thiourea						
Control	17.38	39.78	57.16	30.41	37.00	644.96
Seed soaking @ 500ppm	17.72	40.38	58.11	30.51	37.09	659.15
Seed soaking @ 1000ppm	17.85	40.86	58.71	30.47	37.19	665.97
Foliar spray @ 500 ppm	17.97	41.15	59.12	30.41	37.28	671.83
Foliar spray @ 1000 ppm	18.15	41.37	59.52	30.50	37.40	680.88
Seed soaking @ 500 ppm + Foliar spray @ 500 ppm	18.35	41.84	60.19	30.47	37.49	688.84
Seed soaking @ 1000 ppm + Foliar spray @ 1000 ppm	18.53	42.27	60.00	30.47	37.40	694.48
SE m ±	0.670	1.543	2.207	0.141	0.321	26.56
CD (P = 0.05)	NS	NS	NS	NS	NS	NS

Table 3. Economics of the mustard crop as affected by residual vermicompost and thiourea from the preceding crop

Treatments	Net returns (Rs/ha)	B:C ratio
Vermicompost (t/ha)		
0.0	31096	3.72
1.5	35700	4.28
3.0	41894	5.02
4.5	43320	5.19
SE m ±	1077	0.129
CD (P = 0.05)	3319	0.398
Thiourea		
Control	36451	4.37
Seed soaking @ 500 ppm	37298	4.47
Seed soaking @ 1000 ppm	37656	4.51
Foliar spray @ 500 ppm	37970	4.55
Foliar spray @ 1000 ppm	38398	4.60
Seed soaking @ 500 ppm + Foliar spray @ 500 ppm	38394	4.66
Seed soaking @ 1000 ppm + Foliar spray @ 1000 ppm	1733	4.72
SE m ±	1733	0.208
C.D. (P = 0.05)	NS	NS

soil for longer periods of time which is not enough to affect the phenological characteristics of succeeding mustard crop.

Economical study was also worked out to see the effect of residual content of vermicompost and thiourea of the preceding crop on to the succeeding mustard crop (Table 3) taking in to account the pearlmillet-mustard cropping system. Data in Table 3 showed that the application of various levels of vermicompost in the preceding crop brought significant variation in the succeeding mustard crop during both the year of experimentation. The pooled result showed the highest net return of Rs. 43, 320 in the plots in which vermicompost was applied @ 4.5 t/ha in the preceding crop and it was found to be more than 39.30 and 21.35% over the control and 1.5 t/ha treatments, respectively.

While studying the benefit: cost ratio, it has been found that treatment with application of vermicompost @ 3.0 and 4.5 t/ha in the preceding crop do not vary significantly with each other. However, over control and 1.5 t/ha treatments it was found to be more by 34.72 and 17.35 % respectively.

Thus, it was concluded from the study that the application of vermicompost has a significant residual effect on the suceeding crop up to a certain extent which is 3.0 t/ha and above that though it does not have a negative effect but economically it is better to apply vermicompost @ 3.0 t/ha especially in pearlmillet-mustard cropping system.

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Response of urea and growth regulators on bearing and quality of "Amrapali" mango

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ABSTRACT

To assess the impact of foliar spray of urea (2 %), thio-urea (1000 ppm), and PGRs (GA_3 100ppm, NAA 40 ppm, ethephon 200 ppm, SA 100 and 200 ppm and triadimefon 1000 and 2000 ppm) alone and incombination with urea 2% on bearing and fruit quality of Amrapali mango under agro-climatic condition of Ranchi were carried out at the Department of Horticulture, Birsa Agriculture University, Jharkhand during two fruiting season experiments 2008-2010. Maximum duration of panicle emergence (37 days) and minimum days required for anthesis (19.33 days) were observed from ethephon 200 ppm treated tree. However, increased intensity of flowering shoot (88.50%) and maximum fruit retention per panicle (5.41%) were observed with SA 100ppm in combination with urea spray over control (water spray). The highest yield per tree (16.21 kg) was recorded under plant treated with SA 200 ppm in combination with urea 2 percent. The highest total sugar (11.97%) as well as non reducing sugar (9.51%)were estimated in the fruits of the plant sprayed with triadimefon 200 ppm. While, the highest increase in ascorbic acid and β-carotene were measured from the fruits of the plant sprayed with triadimefon 2000 ppm in combination with urea 2 percent. Beside these, salicylic acid 100 ppm along with urea 2 percent recorded minimum spoilage (10.62%) over control.

Key words : Plant growth regulators, mango, yield, quality.

Despite the largest production base of mango in the world with respect to number of varieties grown and area under cultivation, the productivity of mango in India is low, which adversely affect the economic potentialities of its production. Among several reasons for low productivity, flower initiation and high incidence of fruit drop has been a problem of serious concern (Chacko *et al.* 1982; Murti and Upreti, 1999).

Several studies on different fruit crop have shown that plant growth regulations have potential to enhance productivity of fruits by bringing out a change in nutritional and hormonal status of the plant (Tripathi and Shukla, 2006; Singh *et al.* 2007). It is evident from the reports of Aly *et al.* (2000), Baghel *et al.* (1987) and Bhati and Yadav (2003) conducted on different fruit crops that bearing habit of mango fruit is brought to be triggered by GA_3, NAA and ethephon. Recently, Salicylic acid ($C_7H_6O_3$) and triadimefon (Triazole group) have been accepted as a new plant growth regulator and found to generate a wide range of metabolic and physiological responses in plants by affecting growth and development (Amal *et al.*, 2009; Davis *et al.* 1988). It has also been established that triadimefon (Bayleton) posses a chlorophenyl which can protect plant against various stresses (Thind and Kaur, 2006). Plant nutrition, particularly the level of N has more influence on growth, yield and quality of fruits than any other single plant nutrient and has seen shown to be integral part for routine orchard management (Klein, 2002 and Nestby and Tangliavini, 2005). The application of foliar nitrogen and plant growth regulator can provide significant economic advantages to mango growers when used in appropriate situation as they have proven to be effective in stimulating number of desired responses such as increase in bearing ability, reducing pre -harvest fruit drop as well as increase in shelf life of fruit. Therefore, this study was initiated with the objective to study the impact and efficacy of foliar N applied through urea and thio- urea and PGRs alone or in combination with urea on fruit production along with quality and spoilage of 'Amrapali' mango.

MATERIALS AND METHODS

The study was conducted on 10 years old uniform and well managed 'Amrapali' mango plants which were spaced at about 5 x 5m growing at Horticulture garden Department of Horticulture, University of Birsa, Ranchi in two fruiting seasons from 2008 to 2010. Altogether, there were seventeen treatments with three replications using single plant as a treatment unit in Randomized Block Design (RBD). The treatments were T_1 = urea 2%, T_2 = thio-urea 1000 ppm; T_3 = GA_3 100 ppm; T_4 = NAA 40 ppm; T_5 = ethephon 200 ppm; T_6 = SA 100 ppm; T_7 = SA 200 ppm; T_8 = triadimefon 1000 ppm; T_9 = triadimefon 2000 ppm ; T_{10} = GA_3 100 pm urea 2(%); T_{11} = NAA 40 ppm + urea 2 (%); T_{12} = ethephon 200 ppm + urea 2 (%) ; T_{13} = SA 100 ppm + urea 2 (%); T_{14} = SA 200 ppm + urea 2 (%); T_{15} = triadimefon 1000 ppm + urea 2 (%); T_{16} = triadimefon 2000 ppm + urea 2 (%) and T_{17} = Control (water spray). Aqueous solution of all the treatments was prepared and sprayed on whole tree to run off. In order to give a clear understanding, the extent of flowering and fruit retention 10 uniforn shoot were selected randomly in each treatment and tagged. Duration of panicle emergence as well as flowering, days to 50% flowering were calculated in days after spraying of chemicals and they were recorded by visual observation through regular visiting to orchard. Fruit drop percent as well as number of fruit retention per panicle on the tagged shoot initially and at the time of fruit maturity were counted. Samples of 30 representative fruits were collected randomly from all sides of each plant and average fruit weight (g) and fruit volume were calculated. The cull (under sized) fruits were seperated and only marketable yield were recorded at the time of harvesting from each plant individually and expressed as kilogramme/ plant. The fruit pulp quality analysis including ascorbic acid, total sugar as well as non reducing sugar, TSS/acid ratio and β carotene were done following standard producers.

"Amrapali" mango fruits were harvested at commercial maturity from the orchard. Thereafter, fruits were transferred into bamboo baskets and kept at ambient condition (26-32 and 65-75% RH) for about 2 weeks in different lots. Fruits were assessed daily during spoilage evaluation for skin colour and firmness changes. Subjective visual skin colour ratings were; i) 100% green; ii) 25% yellow; iii) 50% yellow; iv) 75% yellow and v) 100% yellow (Macnish *et al.*, 1997). Hand firmness rating were i) hand; ii) firm; iii) slightly soft; iv) soft, and iv) very soft (Joyce and Shorter, 1995).

RESULTS AND DISCUSSION

All the experimental treatments significantly extended the duration of panicle emergence and shortened the days required for anthesis compared with control (Table1). Maximum duration of panicle emergence (37 days) was observed from ethephon 200 ppm treated tree while, minimum duration of panicle emergence (24 days) was observed from control tree (water sprayed). Similarly, minimum day required for anthesis from ethephon 200 ppm treated tree (19.33 days) which was almost equally effective with treatment triadimefon 1000 ppm (19.83 days) whereas maximum days 29.50 was required from anthesis from tree treated with water only (control). Early differentiation of buds and anthesis from both ethephon and triadimefon treated plants were probably due to suppression of vegetative growth. The minimum days taken to 50% flowering (73.54) were recorded at 200 ppm ethephon. The next equally effective treatments with each other were ethephon 200 ppm + urea 2 percent (76.35 days) and triadimefon 1000 ppm + urea 2 percent (76.86 days). Applying triadimefon (2000 ppm) combined with urea 2 percent increased the intensity of flowering shoot (88.50%) in fruit plant which was almost equally effective with SA 100 ppm + urea 2 (%) sprayed fruit plant. Minimum intensity of flowering shoot (48.67%) was observed in water sprayed fruit tree (control). In mango exogenous application of ethephon inhibited vegetative growth of shoot

Table 1. Effect of chemicals on flowering characters on Amrapali mango

Treatments		Duration of panicle emergence	Duration of flowering (Days)	Days to 50% flowering	Percentage of flowering shoot
		Pooled	Pooled	Pooled	Pooled
T_1	(Urea-2%)	30.50	27.00	84.15	55.05 (48.08)
T_2	(Thiourea-1000 ppm)	32.50	23.83	81.02	61.44 (51.91)
T_3	(GA3-100 ppm)	28.00	24.50	81.59	58.25 (50.00)
T_4	(NAA-40 ppm)	29.50	26.00	83.80	72.79 (58.66)
T_5	(Ethephon 200 ppm)	37.00	19.33	73.54	82.82 (65.49)
T_6	(Salicylic Acid-100 ppm)	34.50	23.34	78.17	84.85 (67.15)
T_7	(Salicylic Acid-200 ppm)	35.50	21.67	77.28	86.17 (68.19)
T_8	(Triadimefon- 1000 ppm)	32.00	19.83	80.20	85.07 (67.81)
T_9	(Triadimefon- 2000 ppm)	36.00	22.17	77.11	88.21 (73.47)
T_{10}	(GA3100ppm + Urea-2%)	30.00	27.17	83.19	68.50 (56.01)
T_{11}	(NAA40ppm + Urea-2%)	28.50	25.17	84.94	72.27 (58.45)
T_{12}	(Ethephon 200ppm + Urea-2%)	33.50	23.17	76.35	82.03 (64.98)
T_{13}	(SA 100 ppm + Urea-2%)	34.00	21.84	78.00	88.50 (70.23)
T_{14}	(SA 200 ppm + Urea-2%)	33.50	20.67	77.09	84.80 (70.60)
T_{15}	(Tri 1000 ppm + Urea-2%)	33.50	22.17	76.86	88.50 (66.26)
T_{16}	(Tri 2000 ppm + Urea-2%)	31.50	24.50	81.83	88.50 (66.55)
T_{17}	Control (Water spray)	24.00	29.50	89.57	48.67 (38.12)
	SEm (±)	0.88	0.941	2.13	3.13
	C.D. (5%)	2.49	2.66	6.03	9.47
	CV (%)	7.34	10.93	6.07	7.22

and promoted floweirng has been reported by Chacko *et al.* (1972). High intensity of flowering shoot in fruit plant treated with triadimefon may be due to its ability to reduce GA_3 biosynthesis in shoot meristem. There are evidences that GA_3 play an inhibitory role in mango flowering (Tomar, 1984). Similarly, salicylic acid also have greatest floric activity and enhance flowering in fruit plant (Metwally *et al.*, 2003).

The mean maximum fruit retention per panicle (5.41%) at the time of harvest was recorded at SA 100 ppm in combination with urea spray as compared to mean minimum in control i.e. fruit retention of 1.42 percent. Whereas next effective treatments were SA 200 ppm + urea 2% and triadimefon 2000 ppm alone which exhibited statistically at par with each others. Similarly, minimum fruit drop was observed in SA 100 ppm combined with urea 2 percent which was comparable with SA 200 ppm mixed with urea 2 percent. The developing fruits need auxin in higher quantity and fruit drop occurs when auxin levels goes down. SA plays on important role in regulating number of physiological process including synthesis of auxin and/or cytokinin. Furthermore, nitrogen in the form of urea also triggered the synthesis at tryptophan, a precursor of auxin, leading to prevented fruit drop resulted into increase in fruit retention. The results approved to same extent with Chauhan and Gupta (1985) and Yadav *et al.* (2004) .

The data presented in same table indicates that the highest fruit weight (252.73 g) as well as fruit volume (231.12 cc) was obtained from tree treated with ethephon 200 ppm combined with urea 2 percent, statistically similar to 100 ppm

Table 2. Effect of chemicals on Fruiting characters on Amrapali mango

Treatments	Fruit drops (%)	Fruit retention per panicle (number)	Fruit weight (g)	Fruit volume (cc)	Marketable Yield (kg/tree)	Percentage increase
	Pooled	Pooled	Pooled	Pooled	Pooled	
T_1 (Urea-2%)	92.77 (74.22)	2.11	205.56	198.08	7.40	12.12
T_2 (Thiourea-1000 ppm)	92.20 (73.79)	2.59	218.75	193.88	9.48	43.63
T_3 (GA3-100 ppm)	91.77 (73.36)	2.59	250.47	226.09	9.52	44.24
T_4 (NAA-40 ppm)	93.05 (74.71)	2.25	206.10	188.06	8.83	33.78
T_5 (Ethephon 200 ppm)	91.23 (72.77)	3.36	230.71	213.66	11.62	76.06
T_6 (Salicylic Acid-100 ppm)	89.32 (70.92)	4.20	213.77	194.56	14.47	119.24
T_7 (Salicylic Acid-200 ppm)	89.61 (71.16)	4.43	196.31	184.71	14.55	120.45
T_8 (Triadimefon- 1000 ppm)	90.31 (71.58)	4.01	205.87	186.73	14.30	116.66
T_9 (Triadimefon- 2000 ppm)	88.81 (71.03)	4.83	198.97	175.33	14.59	119.96
T_{10} (GA3100ppm + Urea-2%)	91.60 (73.21)	2.58	235.58	219.90	9.71	47.12
T_{11} (NAA40ppm + Urea-2%)	92.88 (73.94)	2.60	216.97	199.73	9.73	46.51
T_{12} (Ethephon 200 ppm + Urea-2%)	90.87 (72.34)	3.13	252.73	231.12	11.03	66.51
T_{13} (SA 100 ppm + Urea-2%)	88.16 (69.85)	5.41	187.60	176.21	16.06	143.33
T_{14} (SA 200 ppm + Urea-2%)	88.62 (68.71)	4.64	191.60	178.63	16.21	145.60
T_{15} (Tri 1000 ppm + Urea-2%)	90.19 (71.75)	4.06	188.20	175.46	13.53	104.09
T_{16} (Tri 2000 ppm + Urea-2%)	89.93 (70.43)	3.85	189.14	175.80	13.46	103.93
T_{17} Control (Water spray)	94.39 (75.29)	1.42	166.24	161.40	6.60	
SEm (±)	0.75	0.16	7.48	5.96	0.70	
C.D. (5%)	2.29	0.47	21.12	16.84	1.99	
CV (%)	1.48	14.16	9.51	6.82	13.41	

Table 3. Effect of chemicals on Physico-chemical characters on Amrapali mango

Treatments plant		Total sugar (%)	Non - reducing sugar (%)	Ascorbic acid (mg/100ml)	TSS/Acid	β- Carotene (I.U.)	Spoilage (%)	Average Return s/ (Rs)
		Pooled	Pooled	Pooled	Pooled	Pooled	Pooled	
T_1	(Urea-2%)	8.99	5.89	39.39	70.56	12285.43	13.15 (21.18)	205.25
T_2	(Thiourea-1000 ppm)	7.51	4.65	48.21	62.10	12404.20	12.01 (20.23)	259.75
T_3	(GA3-100 ppm)	8.49	5.16	51.33	98.99	12325.02	13.21 (21.26)	263.00
T_4	(NAA-40 ppm)	10.50	7.53	49.61	107.32	12310.17	12.90 (21.02)	240.00
T_5	(Ethephon 200 ppm)	7.62	4.83	35.25	83.35	12305.22	12.26 (20.44)	320.87
T_6	(Salicylic Acid-100 ppm)	8.22	6.09	35.95	107.17	12329.97	11.44 (19.75)	401.17
T_7	(Salicylic Acid-200 ppm)	8.47	6.42	44.86	108.65	12369.56	11.51 (19.82)	401.77
T_8	(Triadimefon- 1000 ppm)	8.03	5.63	42.28	89.14	11993.4 4	11.79 (19.99)	393.82
T_9	(Triadimefon- 2000 ppm)	11.97	9.52	39.15	74.48	12067.68	12.57 (20.71)	397.32
T_{10}	(GA3100ppm + Urea-2%)	9.26	6.34	48.44	63.32	12518.02	14.50 (22.36)	267.00
T_{11}	(NAA40ppm + Urea-2%)	8.00	6.12	38.06	58.78	12621.95	13.16 (21.19)	271.15
T_{12}	(Ethephon 200ppm + Urea-2%)	7.95	4.85	55.78	83.04	12621.95	13.12 (21.19)	305.27
T_{13}	(SA 100 ppm + Urea-2%)	9.29	6.68	40.06	78.13	12612.05	10.62 (18.98)	444.27
T_{14}	(SA 200 ppm + Urea-2%)	8.02	5.34	48.68	103.91	12587.31	13.09 (21.20)	454.70
T_{15}	(Tri 1000 ppm + Urea-2%)	7.75	5.04	45.32	69.81	12626.90	11.28 (19.59)	369.62
T_{16}	(Tri 2000 ppm + Urea-2%)	10.03	6.70	57.81	71.62	12656.59	13.38 (21.37)	369.65
T_{17}	Control (Water spray)	7.57	5.23	35.87	112.50	12537.82	19.77 (26.37)	182.45
		SEm (±)	0.25	0.298	1.746	7.28	168.48	1.08
		C.D. (5%)	0.70	0.902	4.93	20.56	475.67	NS
		CV (%)	8.32	7.034	12.23	23.07	0.48	7.3

GA_3 treatment followed by mixture (GA_3 100 ppm + urea 2 percent) treatments. The possible reason behind increasing the fruit weight and volume might be due to the rapid cell division and cell enlargement and also due to hormone mediated direct transportation, accumulation and ensure balanced partitioning of photosynthetic assimilates to developing fruit (Sink). Further, this increase in volume and weight were more partly due to average fruiting per tree in both the treatments which possibly reduced the competition between fruits for photosynthetic assimilates. The corroborative results of fruit weight and volume was reported by Gupta and Kaur (2007) in Sutlug plum with ethephon.

The same table shows that the maximum yield in terms of kilogramme per tree was obtained with plant treated with SA 200 ppm in combination with urea 2 percent, statistically similar to the treatment (SA 100 ppm + urea 2%). The results are in agreement with findings of Singh *et al.* (2001) in mango with SA. Improvement in yield due to combination of SA with urea might be the result of enhanced assimilating power of leaves to synthesize more organic metabolites (Seagel *et al.*, 2008). Further, increased fruit retention per panicle resulting in more fruit per tree which in turn was favourable in enhancing the fruit yield per tree.

The mean data in Table 3 clearly indicates that highest total sugar (11.97%) as well as non reducing sugar (9.51%) in the fruits of the plant sprayed with triadimefon 200 ppm followed by NAA 40 ppm (10.50% and 7.53% respectively). Total sugar and non reducing sugar content were recorded lowest in the fruit from the plants treated with thio-urea 1000 ppm (7.51% and 4.65% respectively). Increase in total sugar with triadimefon treatment was reported by Thuind and Kaur (2006) in Ber and Tripathi and Sukla (2006) im straw berry. The increase in total sugar may be because of transformation of organic acids into sugars. The ascorbic acid and -carotene were measured highest (57.81 ml/100 ml and 12656.5.1.0) from the fruits of the plants sprayed with triadimefon 2000 ppm incombination with urea 2 percent. Lowest ascorbic acid of 35.87 mg/100 ml was measured in fruit treated with water (control) whereas lowest -carotene recorded in triadimefon 2000 ppm (12067.678 i.u). The higher ascorbic acid content may probably be due to the catalytic influence of triadminefon on the biosynthesis of ascorbic acid from sugar. -carotene content in triadimefom treated fruit in highly correlated with anti-oxidant activity and anti-oxidant enzyme as reported by Sujatha (1999).

The spoilage loss percent as adjudged from Table 3 revealed that the treatment SA 100 ppm with urea 2 percent recorded minimum spoilage (10.62%) on 15th day, statistically at par with triadimefon 1000 ppm in combination with urea 2 percent (11.28%) and salicylic acid 100 ppm (11.44%).

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Detection of transgressive segregants for quantitative characters in F_3 generation of in-ovulo cultured interspecific triple cross of cotton viz; colchicide (*G. arboreum x G. anomalum*) *x G. barbandense*

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ABSTRACT

In the present investigation, the F_3 segregating generations of interspecific triple cross between colchicide (*G. arboreum* x *G. anomalum*) x *G. barbandense* were evaluated with an objective to detect transgressive segregants for quantitative characters. Very high numbers of transgressive segregants were observed in F3 generation of interspecific triple cross for nine yield contributing characters. Looking towards the range of variation for yield and yield contributing characters it appears that very high amount of variability has been created among the progenies. The vast variation in transgressents also suggested the possibility of combining desirable genes from all the three species together. In most of the segregants in F_3 generation, seed cotton yield of better parent was found to be transgressed simultaneously with transgression of one or more other characters. The most promising transgressive segregants observed in F_3 generation also had higher intensity of expression than the increasing parent for one or more characters. These entries need to be evaluated for their performance vis-a-vis their hybrids and commercial hybrids. On the basis of observed high values of trangressive segregants, it can be concluded that, when desired intensity of character is not available in the parents, transgressive breeding may be successfully used to extend the limit of expression of a particular character.

India is the only country to grow all the four species of cultivated cotton, i.e *G. arboreum, G. herbaceum, G barbadense and G. hirsutum* and has about 9 million hectares under cotton; the largest of any nations in the world, this acreage is about 25% of the total acreage in the world and 5% of India's cultivated area. Nonetheless, productivity levels are very low with 502 kg/ha as against world average of 731 kg/ha. The yield and the fiber quality are priorities in most of the cotton breeding programmes, but they are constrained by insects and pathogens causing the diseases as well as the environmental stresses. Only about 60 % of the genetic potential is utilized due to pest and abiotic stress losses. Thus the primary objective of programme for the genetic improvement for resistance to pests and stresses is to develop cultivars, that are resistant to one or more pests, while improving or maintaining their basic agronomic yield, fiber and seed characteristics.

Traditional methods of cotton breeding often fail due to incompatibility barriers like embryo or endosperm abortion (Pundir, 1972) Even in cases where hybridization is effective the frequency of hybrid formation is very low and eventually there is hybrid breakdown (Gerstel and Phillips, 1958) Therefore the desirable traits like fibre length and fineness and resistance to black arm disease, wilt and insect which though present in various species can not be transferred into cultivated types. In the present investigation, successful production of inter-specific hybrid is done by utilizing the techniques of in-vitro production in cotton. Many plant breeders have reported transgressive segregation in hybrid progenies and suggested that transgressive segregation may be used as a positive tool in plant breeding. A character absent in the original parent may appear in the segregating generation (Gardner, 1968). Genetically diverse parents having better combing ability are more likely to give rise to transgressive segregants. As a result the intensity of the character in the new derivative is greater than that in either parent. Here, each parent is expected to contribute different desirable genes, which when brought together by recombination give rise to transgressive segregants.

Thus, considering the current prospects of cotton crop, efforts were made to introgress superior fibre quality parameters from wild G. *anomalum* ($2n=2x=26$ B_1B_1) and G. *barbadense* ($2n=4x=52$, $A_bA_bD_bD_b$) into *G. arboreum* cotton and obtained hybrid between colchicide (*G. arboreum* x *G. anomalum*) x *G. barbandense.* The F_1 and F_2 generations of this triple cross were studied earlier, while F_3 and F_4 segregating generations of this interspecific cross are studied during present investigation for detection of transgressive segregants for various quantitative characters.

MATERIALS AND METHODS

The present research work was conducted at the Cotton Improvement Project, Mahatma Phule Krishi Vidyapeeth, Rahuri, during the period 2005-2009. The material consisted of parent *G. arboreum* (P_1), *G. anomalum* (P_2) and *G. barbadense* (P_3) and F_1 generation of *G. arboreum* x *G. anomalum* (C_1 doubled F_1) and F_1 triple hybrid colchicide (*G. arboreum x G. anomalum*) x *G. barbadense* and segregating generations viz., F_3 and F_4 of the above cross. The F_3 population was obtained by selfing selected F_2 plants, comprising 23 progenies evaluated in two replications. For detection of transgressive segregation the data on individual plants for yield contributing characters were pooled together and means, standard deviation, standard error of means, variances and standard variates were obtained and worked out by following Panse and Sukhatme (1967). The limiting value of standard variates corresponding to the range of parental means at 5% probability level was calculated so that the segregants beyond this limiting value would be transgressants. Transgressive segregation showing significant deviation only in the desirable direction was considered for drawing inferences about transgression for a character.

Limiting value: The limiting normal deviation (N. D) value was calculated as given below (Panse and Sukhatme, 1967).

$$\text{N.D value} = \text{Threshold value} - F_3/\sigma F_3$$

$$\text{Threshold value} = P(+) + 1.96\sigma P(+)$$

where, $P(+)$ = Mean of increasing parent

$\sigma P(+)$ = Standard deviation of increasing parent

σF_3 = standard deviation of F_3

F_3 = Mean of F_3 generation

RESULTS AND DISCUSSION

Frequency distribution and proportion of desirable transgressive segregation for nine yield contributing characters, individually and for combination of characters, along with yield have been recorded for 280 plants in F_3 generation of in-ovulo cultured inter specific triple cross viz., colchicide (*G. arboreum* x *G .anomalum*) X *G. barbadense* in the present investigation. Transgressive segregation in cotton is reported in F_2 and F_3 (Miller and Rawlings, 1967; El-Adl and Miller,1971; Narayanan *et al.*, 1987 and Percy and Turcotte, 1988; Pradeep and Sumalini, 2003; Manivasakam and Kamalanathan, 1987) suggested that selection of transgressants should ideally begin in F_3 generation.

Transgressive segregation was highest for seed cotton yield (89.56 %) followed by seed index (83.91 %), number of sympodia per plant (53.04 %), days to first flower (39.57 %), boll weight (35.21 %) and number of bolls per plant (33.91 %). While monopodia, plant height and ginning percentage contributed least with 8.70, 14.35 and 14.78 per cent respectively (Table 1). (Miller and Rawlings. 1967; El-Adl and Miller, 1971; Manivasakam and Kamalanathan, 1987 and Narayanan *et al.* 1987) reported transgressive segregation in F_2 and F_3 generation for number of bolls per plant, seed cotton yield per plant, ginning percentage and halo lengths .

The frequency of transgressive segregation varied considerably in all the characters studied. Maximum frequency of transgressive segregation was observed for seed cotton yield (206) followed by seed index (193), number of sympodia per plant (122), days to first flower (91) and boll weight (81) in F_3 segregating generation of triple cross determining the desirable alleles contributed by colchicide (*G. arboreum x G. anomalum*) in the segregating generation giving rise to transgressive segregants (Table 1). Pawar *et al.* (2003); Pradeep and Sumalini (2003) also reported transgressive segregation for number of bolls per plant, seed cotton yield, boll weight, halo length, ginning percentage, plant height, number of sympodia per plant and days to first flower.

It is revealed that when the desired intensity of character is not available in the parents, transgressive breeding can be employed to extend the limit of the character. The success in obtaining the desired transgressive segregants depends upon obtaining genetic recombination between both linked and unlinked alleles (Briggs and Allard (1953). There were several combinations of characters in which seed cotton yield was transgressed in conjugation with transgression of other yield contributing characters. From this investigation, it is to point out that observation on nine characters including seed cotton yield were recorded on 280 plants in F_3 generation of triple cross, out of which 206 individual plants transgressed for yield alone or in combination with eight other character beyond the increasing parent. The total number of transgressants in F_3 generation of triple cross for number of sympodia per plant, number of bolls per plant and boll weight in different combinations with seed cotton yield was 122, 10, and 81, respectively. It is clear from this data that in majority of individuals, where better parent yield was transgressed, there was simultaneous transgression of one or more yield components like number of sympodia per plant, number of bolls per plant and boll weight. There are two possible explanations for this situation, the obivious reason for this could be that seed cotton yield is dependent on these yield components. Alternatively there may be linkage drag so that genes of these traits move together. (Leininger and Frey. 1962), working on oat, noticed that genes which determine heading date and plant height were linked with genes for yield. On the basis of this they suggested that there was a linkage drag involving heading date, height and yield genes.Whether it is a linkage drag or dependency on some of the yield components, it can be safely inferred that selection of transgressants for number of sympodia per plant, number of bolls per plant and boll weight will lead to increase in yield.

Plant number 57 followed by plant number 51, 53, 116, 119, 47, 44 and 228 were found to be the most promising transgressive segregants in

Table 1. Threshold value, frequency and range of transgressive segregants for nine quantitative characters in F_3 generation of the in-ovulo cultured interspecific triple cross *viz.*, colchicide (*G. arboreum x G.anomalum*) x *G. barbadense*

Sr. No.	Characters	Threshold value	Transgressive segregants			
			Frequency	Normal deviation (N. D) value	Percent (%) transgressive segregants	Range
1	Plant Height(cm)	150.24	33	1.19	14.35	151 to170.9
2	No. of Monopodia	2.62	20	1.53	8.70	2.62 to 3
3	No. of Sympodia	14.17	122	10.58	53.04	15 to 25
4	Days to first flower	62.22	91	51.52	39.57	51 to 62
5	Nos. of bolls/plant	33.53	10	29.68	33.91	34 to 48
6	Boll weight (g)	2.54	81	4.32	35.21	2.54 to 3.05
7	Seed index (g)	8.01	193	0.08	83.91	8.02 to11.73
8	Ginning %	37.36	34	28.62	14.78	37.48 to 43.61
9	Seed cotton yield(g)	46.60	206	41.88	89.56	46.65 to 89.9

Table 2. **Promising transgressive segregants having combination of desirable attributes in F3 generation**

Generation	Plant No	Plant height	Monopodia	Sympodia	Days to first flower	Number of Bolls /plant	Boll weight (g)	Seed index	Ginning percentage	Seed Cotton Yield (SCY)	% SCY increase over increasing parent
F3	44	156.33*	2.00	20*	62*	38*	2.92*	8.84*	32.45	68.78*	65.34
	47	138.6	2.00	16*	61*	39*	2.92*	8.91*	38.27*	75.66*	81.88
	51	160.53*	2.00	15*	58*	47*	2.02	9.77*	38.8*	85.27*	104.98
	53	164.51*	2.00	18*	62*	45*	2.01	9.81*	37.73*	84.36*	102.79
	57	169.44*	2.00	16*	61*	44*	2.01	9.42*	39.88*	88.82*	113.51
	116	153.77*	2.00	12.00	58*	41*	2.54*	8.23*	39.92*	79.91*	92.09
	119	164.12*	2.00	15*	62*	35*	2.58*	8.08*	35.55	77.12*	85.38
	228	131.3	2.00	16*	57*	34*	2.61*	9.03*	37.85*	66.22*	59.18
P1		**131.34**	**1.30**	**8.30**	**59.30**	**11.60**	**1.94**	**7.08**	**34.09.**	**41.60.**	
P2		**139.70**	**1.80**	**10.70**	**71.70**	**27.00**	**0.57**	**3.78**	**24.30**	**14.87**	
P3		**127.68**	**1.60**	**9.00**	**68.70**	**14.00**	**2.46**	**7.25**	**33.08**	**37.55**	

the F3 generation of triple cross, for seed cotton yield giving 113.5 ,104.98, 102.79, 92.09, 85.38, 81.88, 65.34 and 59.18 per cent higher yield respectively, in addition to higher intensity of expression for plant height, number of sympodia per plant, number of bolls per plant, seed index, ginning percentage. While, plant no 228 followed by 116 and 51 were found to be promising transgregants in respect of earlyness for days to first flower than the better parent. As, of the three parents *G. arboreum* was early flowering (59.30 days) than *G. barbadense* (68.70) and *G. anomalum* (71.70). The transgressive segregants with early flowering ranged from 51 to 62 days at 5% probability level (Table 2). In addition these segregants had higher intensity of expression than the increasing parent for one or more other characters except for number of monopodia per plant and also had higher values for rest of the characters than the decreasing parent at 5% probability level.

Transgressive segregants in the F_2 may arise due to dominance and dominance interactions in addition to additive x additive interaction which is fixable, due to recombination of genes with positive effects and responsible for the production of transgressive segregates in the F_3 generation. The findings, therefore, also revealed that the parents differed for many genes and introgression of genes from *Gossypium anomalum* created large amount of genetic variability for yield and fibre components in most of the individual progenies, suggesting the scope to use this material in the future breeding programme. Similar results were also reported in lentil (Kant and Singh, 1998). In spite of the constraints like finely tuned genetic system controlling lint quality, strength and texture,hybrid breakdown, high-negative correlation between high yield and fibre strength (Harland, 1970; Stephens, 1950; Lewis, 1957) the recovered transgressive segregants (Stephens, 1944) would afford vast opportunities in selecting plants with desired attributes from segregating populations and introgression of genes from wild *Gossypium anomalum* to commercial cultivars (Richmond, 1950; Meyer, 1974). The individual progenies which gave high frequency of transgressive segregants for yield per plant accompanied with desirable fibre properties in both the generations may be preferred in on-going breeding programme. And above all if Bt gene is incorporated into these hybrids, they will be an excellent source of bollworms tolerance coupled with superior fibre properties and yield.

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Integrated weed management in cauliflower cv. 'Pusa Snowball K-1'

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ABSTRACT

A field experiment was undertaken at Rajasthan College of Agriculture, Udaipur to evaluate the effect of different weed management practices on weed dynamics in cauliflower (*Brassica oleracea* var. *botrytis* L.) cv. 'Pusa Snowball K-1' during the year 2009-10. The treatments comprising ten weed control methods were weedy check, two hand weedings i.e. 35 and 60 days after transplanting (DAT), black plastic mulch, rice straw mulch and three herbicides (fluchloralin at 1.5 kg/ha, pendimethalin at 1.5 kg/ha and alachlor at 2 kg/ha) alone and in combination with one hand weeding at 35 DAT. Among the different treatments the black plastic mulch treated plot showed excellent weed control. The growth (plant height, spread and number of leaves), quality (compactness, color and per cent protein content of curd) and yield were also higher under black plastic mulch but it was not significantly different with rice straw mulch. Among the herbicides pendimethalin in combination with one hand weeding was found most effective. The results further revealed that the rice straw mulch gave highest benefit:cost ratio of 3.48: 1.

Key words: Black plastic, cauliflower, herbicides, mulching, rice straw, weeds.

Cauliflower (*Brassica oleracea* var. *botrytis* L.) is one of the most popular vegetable crop among the cole crops. It is grown for its white tender curd formed by shortened floral parts which is used for vegetable, curry, soup and pickle preparation. Besides being good source of protein and carbohydrate, cauliflower is a rich source of vitamins and minerals. Because of this it has gained a lot of importance among the researchers, farmers and consumers who are seeking nutritional security. The immense importance of cauliflower makes it imperative for the horticulturists to overcome major constraints in its cultivation. For profitable cultivation of cauliflower, control of weeds is necessary because longer period of weed-cauliflower competition greatly reduce crop growth and curd yield. Average reduction in shoot dry weight and curd yield were 81 per cent and 89 per cent, respectively (Qasem, 2009). It is an established fact that weeds can be controlled effectively by manual hand weedings. But presently labour has become very costly and their non-availability at proper time makes the daunting task of weed control further challenging. Whereas, use of herbicides alone may not be the answer to the problem because environmentalists claims them dangerous for sustainable agriculture. Thus appropriate choice for weed control in cauliflower would be an integration of cultural and herbicidal control for boosting the cauliflower production. Besides hand weeding and herbicidal control, mulching (particularly plastic mulch and rice straw mulch) has also been advocated by many researchers as an effective mean for reducing weed population. Most studies aiming at reducing herbicide reliance have focused on combining herbicides with cultivation and weed-suppressive cover crops, residues or living mulches and in existing tillage systems (Brandsaeter and Netland, 1999). Therefore, the present investigation was planned to assess the effect of different weed management treatments on weed dynamics and growth, yield and quality of cauliflower.

MATERIALS AND METHODS

The field experiment was conducted at Hi-

Tech unit, Rajasthan College of Agriculture (located at 24°35 N latitude and 24° 42 E longitudes at an elevation of 579.5 m above mean sea level), Udaipur. The soil of experimental site was clay loam in texture, slightly alkaline in reaction, low in available nitrogen (186.5 kg/ha) and medium in available phosphorus (25.5 kg/ha) and potassium (252.5 kg/ha). The experiment with 10 treatments was laid out in a randomized block design with 3 replications. These 10 treatments include weedy check, two hand weedings (35 and 60 days after transplanting), three herbicides (fluchloralin at 1.5 kg/ha, pendimethalin at 1.5 kg/ha and alachlor at 2 kg/ha) alone and in combination with one hand weeding at 35 days after transplanting (DAT) and two mulches viz. black plastic mulch (400 gauge) and rice straw mulch. Transplanting of about five weeks old seedlings of 'Pusa Snowball K-1' cauliflower was done on second week of November, 2009 at a spacing of 50 cm x 50 cm. The plot size was 2.50 m x 1.50 m and the number of plants per plot was 15. The crop was irrigated immediately after transplanting. The growth parameters recorded were plant height, plant spread and number of leaves per plant (each at 60 DAT and at harvest), days taken to curd initiation and days taken to curd maturity (at harvest). To calculate different readings five plants were selected randomly from each plot and tagged permanently. Among the quality parameters the diameter of curd was calculated by measuring circumference of the curd while compactness and color of curd were examined and marked (out of 10) by a panel of experts and the protein content of curd was determined by multiplying nitrogen concentration with a factor 6.25. To calculate the weed density (weed/m^2), Grassy, broad leaved weeds (BLW) and total weed species were counted with the help of a quadrant measuring 0.5 X 0.5 m^2 by placing randomly at two places in each plot. The weed species were counted at 35 DAT, 60 DAT and at the time of harvesting of the crop. Similarly, biomass of weeds at 35 DAT, 60 DAT (using iron quadrant of 0.25 x 0.25 m^2) and at harvested stage (weeds from whole plot) was recorded by weighing fresh sample and computing the dry matter by weighing of 100 gram weed sample after oven drying it at 70°C for 24 hours. Weed control efficiency (WCE) was calculated at harvest by using the formula:

$$\text{WCE (\%)} = (\text{DMC}-\text{DMT})/\text{DMC} \times 100$$

where, DMC= Dry weed production of weeds in weedy check plot; DMT= Dry weed production of weeds in treated plot.

RESULTS AND DISCUSSION

Effect on growth parameters

The data enshrined in Table 1 shows that the maximum growth in terms of plant height (52.53 cm on 60 DAT and 56.23 cm at harvest), number of leaves (20.24 on 60 DAT and 23.23 at harvest) plant spread (2445.76 cm^2 on 60 DAT and 3469.38 cm at harvest) were obtained with black plastic mulch followed by rice straw mulch and least under weedy check. Similarly, black plastic mulch treated plot recorded least number of days to reach curd initiation (68 days) and curd maturity (92.8 days) followed by rice straw mulch. Among the herbicide + hand weeding combinations, the pendimethalin at 1.5 kg/ha + one hand weeding at 35 DAT treatment performed better than other combinations. The number of weed were low in above best performing treatments resulting into lesser crop-weed competition for light, nutrients, moisture and space resulting into increasing availability of assimilates for growth and developments of plants (Mal *et al.* 2005). Number of leaves were lowest in weedy check since it has highest weed intensity which might have altered the spectral photon distribution within the canopy (Mal *et al.* 2005) thus affected the plant development. Bhayan *et al.* (1985) reported that weed control treatments increased availability of nutrients, moisture and space to crop which results into more biomass accumulation ultimately increased number of leaves. The difference depends upon effectiveness of different treatments in controlling weed population. Days taken to curd initiation and maturity are markedly shortened because of rise in temperature under the mulch conditions (Juan, 2009; Subrahmaniyan and Zhou, 2008).

Effect on yield attributes

As far as yield attributes are concerned

Table 1. Effect of weed management on growth parameters

Treatments	Plant height (cm)		Plant Spread (cm²)		Number of leaves/ plant		Days taken to curd initiation	Days taken to curd maturity
	60 DAT	At harvest	60 DAT	At harvest	60 DAT	At harvest		
Weedy check	43.50	46.43	1781.21	2772.95	18.27	21.37	74.93	99.70
Fluchloralin at 1.5 kg/ha	47.07	49.47	2080.90	3015.88	18.37	21.64	73.43	97.40
Pendimethalin at 1.5 kg/ha	48.43	51.07	2218.43	3192.04	18.33	21.73	72.27	96.27
Alachlor at 2 kg/ha	46.33	48.80	2019.35	2948.16	18.73	22.10	73.83	97.70
Fluchloralin + 1 hand weeding	49.07	52.43	2276.76	3233.64	19.27	22.97	71.70	95.77
Pendimethalin + 1 hand weeding	50.63	54.33	2330.55	3297.54	19.90	23.53	71.17	95.33
Alachlor + 1 hand weeding	47.91	50.50	2174.43	3101.76	19.23	21.73	72.10	96.17
Black plastic mulch	52.53	56.23	2445.76	3469.38	20.24	23.23	68.00	92.80
Rice straw mulch	51.83	54.87	2383.82	3396.30	20.13	23.20	69.03	93.70
Two hand weeding	48.33	51.07	2228.44	3174.39	18.33	21.83	72.20	96.23
SEm. ±	0.97	0.73	44.55	51.29	0.70	0.79	0.58	0.98
C.D. (P=0.05)	2.87	2.18	132.35	152.40	2.08	2.33	1.71	2.90

Table 2. Effect of weed management on yield attributes, quality characters and economics of different treatments

Treatments	Diameter of curd (cm)	Compactness of curd (out of 10)	Color of curd (out of 10)	Protein content (%)	Weight of curd (g)	Total yield (t/ha)	Harvest index (%)	B: C ratio
Weedy check	11.10	6.23	6.56	2.41	545	11.39	50.29	1.88: 1
Fluchloralin at 1.5 kg/ha	14.27	7.83	7.95	2.45	595	16.64	54.21	2.99: 1
Pendimethalin at 1.5 kg/ha	15.07	8.47	8.11	2.48	617	17.54	56.01	3.17: 1
Alachlor at 2 kg/ha	13.87	7.66	7.49	2.45	587	15.79	52.84	2.81: 1
Fluchloralin + 1 hand weeding	15.80	7.99	8.02	2.58	623	19.21	56.79	3.16: 1
Pendimethalin + 1 hand weeding	16.27	8.52	8.11	2.51	629	20.21	57.96	3.34: 1
Alachlor + 1 hand weeding	15.07	7.57	7.97	2.46	602	17.71	55.72	2.86: 1
Black plastic mulch	17.20	9.31	9.38	2.78	675	26.3	59.97	3.18: 1
Rice straw mulch	16.83	9.28	9.33	2.70	654	24.6	59.88	3.48: 1
Two hand weeding	14.83	8.72	8.70	2.63	619	18.29	55.85	2.77: 1
SEm. ±	0.58	0.12	0.11	0.04	14.6	0.61	0.35	
C.D. (P=0.05)	1.71	0.36	0.33	0.12	44.28	1.82	1.04	

Table 3. Effect of weed management on weed dynamics

Treatments	35 DAT			60 DAT			At harvest		
	Weed density (weed/m^2)	Weed biomass (kg/ha)	WCE (%)	Weed density (weed/m^2)	Weed biomass (kg/ha)	WCE (%)	Weed density (weed/m$^{2)}$	Weed biomass (kg/ha)	WCE (%)
Weedy check	8.65(74.33)	740	-	14.99 (224.33)	2500	-	15.13 (228.30)	3200	-
Fluchloralin at 1.5 kg/ha	5.40 (28.66)	480	35.11	9.41(87.99)	870	65.19	9.50 (89.66)	1150	64.05
Pendimethalin at 1.5 kg/ha	4.56 (20.33)	310	58.10	8.32(68.66)	530	78.80	8.17 (66.33)	770	75.93
Alachlor at 2 kg/ha	5.84(33.66)	500	32.43	9.65 (92.66)	990	60.40	9.54 (90.60)	1230	61.56
Fluchloralin + 1 hand weeding	5.61 (30.99)	490	33.75	6.15(37.32)	440	82.39	5.82 (33.32)	560	82.49
Pendimethalin + 1 hand weeding	4.56 (20.33)	290	60.81	5.43(28.99)	340	86.40	4.98 (24.32)	430	86.56
Alachlor + 1 hand weeding	5.61 (31.00)	520	29.69	6.47(41.32)	510	79.59	6.01 (35.66)	700	78.11
Black plastic mulch	0.71(0.00)	0	100	1.83(2.86)	60	97.44	2.22 (4.45)	120	96.35
Rice straw mulch	2.04(3.66)	800	89.19	3.19(9.66)	150	94.00	3.53 (11.98)	210	93.44
Two hand weeding	9.14(82.99)	750	-*	8.69(74.99)	530	78.79	8.53 (72.34)	780	75.61
SEm. ±	0.04	6.34	0.97	0.06	11.7	0.27	0.05	15.5	0.29
C.D. (P=0.05)	0.11	18.84	2.87	1.19	34.8	0.81	0.16	46.2	0.87

*Values in paranthesis are original values.

different weed control treatments performed significantly better than the weedy check. However, the higher values of different yield attributes viz. average weight of curd per plant (675 g), total yield (26.30 t/ha) and harvest index (59.97%) were observed in black plastic mulch followed by rice straw mulch and pendimethalin at 1.5 kg/ha + one hand weeding at 35 DAT (Table 2). Higher biological yield per plant as observed in these plots might be due to less crop-weed competition for light, nutrients, moisture and space which resulted in increasing availability of assimilates to plant vegetative phase which is directly responsible for better growth of curd and ultimately yield (Bhayan *et al.* 1985). Contrary to this, poor value of these yield parameters recorded in weedy check plot may be ascribed to more crop-weed competition.

Effect on quality parameters

In the present investigation the black plastic mulch resulted into better quality parameters viz. diameter, compactness, color and protein content (Table 2). Whereas, the curds from the weedy check plot were poor in quality. Similar results were observed by Moniruzzaman *et al.* (2007). This is possibly because of balanced and adequate availability of nutrients and simultaneously better use of natural resources such as solar radiation to the crop.

Effect on weed dynamics

Among weeds the broad leaved weeds like *Chenopodium album, Chenopodium murale, Anagelis arvensis* and *Asphodelus tenuifolius* mainly invaded the crop field. Table 3 displays that weed density and weed biomass at different stages were highest in weedy check because weeds were allowed to grow throughout the growing season and removed appreciable amount of nutrients from the soil. Whereas, the minimum weed density and weed biomass were under black plastic mulch followed by rice straw mulch. It is because of suppression of weed growth to a great extent under these treatments. Campiglia and Temperini (2000) revealed the reason that it is because of increased soil temperature under mulch conditions at all depths which reduced weed density as well as weed biomass production. Superiority of weed control methods was estimated in terms of weed control efficiency. Table 3 shows that the maximum weed control efficiency was found in black plastic mulch which might be due to the lowest weed biomass recorded under this treatment as compared to weedy check. Singh and Mir (2005) also obtained the highest weed control efficiency with black polythene mulch in cabbage cv. Pride of India.

Benefit : cost ratio

The yield was recorded highest from black plastic mulch whereas, per unit profit (benefit : cost ratio) was highest (3.48:1) from the rice straw mulch treated plot (Table 2) because this is far cheaper than the plastic mulch. Similar results were reported by Moniruzzaman *et al.* (2007) and Abouziena *et al.* (2008).

Thus, it is inferred that significantly higher weed control efficiency was achieved by using black plastic mulch followed by rice straw mulch. Amongst different weed management practices, use of black plastic mulch registered highest curd yield but it was at par with rice straw mulch. Though the net returns were little higher by use of black plastic mulch, however on account of low cost the use of rice straw mulch resulted in higher B:C ratio than black plastic mulch. Also the quality parameters (diameter, compactness, color and protein content of curd) were at par between these two treatments. Hence, rice straw mulch is recommended for weed control in cauliflower.

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Validation of soil test based fertilizer recommendations for targetted yield of direct sown paddy in north coastal zone of Andhra Pradesh

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ABSTRACT

A field experiment was conducted at RARS, Anakapalle during 2008-2010 to find out the fertilizer requirement for targeted yields. The experiment had five treatments T1 : 100% rec. dose of fertilizers (control) T2,T3,T4 supply of fertilizer based on targeted yield of 5t, 6 t/ha, and 7 t/ha respectively and T5 supply of fertilizer based on 30% change on soil test value. The yield obtained in soil test based targeted yield (STTY) for 7 t/ha (5.24 t/ha) was significantly higher than the recommended dose of fertilizer. The yield response in kg/kg fertilizers was also the highest for this treatment. Again, applying fertilizers based on targeted yield of 7 t/ha recorded the highest while the recommended dose of fertilizers recorded the lowest uptake of nutrients. The available nutrient status in soil after harvesting of paddy was higher in the treatment of targetted yield of 7 t/ha.

Key words : Grain yield, targetted yield, STTY, nutrient uptake

Because of long period of cultivation, yield of paddy crop gradually decreased. Application of chemical fertilizers increased yields. Hence farmers tend to apply fertilizers uniformly at higher quantities than the amounts required. It might, however, be more efficient to chemically analyze the soil and to apply fertilizers depending on both the nutrients that are available from the soil and those that are required by rice plants. Experiments conducted by Gracia 1996; Zennow 1998a, 1998b, c to test the 'balanced nutritional' method for determining the appropriate amounts of fertilizers to produce the highest yield. In India, current fertilizer recommendations are very old, which were developed based on agro-climatic zones. Moreover, farmers add only major nutrients. But, along with major nutrients secondary and micro nutrients are also absorbed by crops resulting in their depletion. The soil-based fertilizer recommendation is desirable to achieve precision in farming with maximum crop production, minimum fertilizer loss and imprived soil health. Hence the study was initiated with an objective to find out the soil test based fertilizer use with targeted productivity in direct sown paddy in North Coastal Zone of A.P.

MATERIALS AND METHODS

A field experiment was conducted at RARS, Anakapalle during 2008- 2010 to find out the soil test based fertilizer recommendation for targeted yield of direct sown paddy in North coastal zone. The experiment was laid out in a randomized block design with four replications. The paddy variety used was RGL 3996. The field was prepared after receiving rainfall and paddy seed was sown directly in the field during the month of July. The experimental field had sandy loam soil with available N 240 kgha^{-1} (low), available P 29 kg P_2O_5 /ha (medium), available K 290 kg K_2O ha^{-1} (high). The STCR equation was FN = 3.47T-0.37SN, FP_2O_5 = 2.53T-2.12SP, FK_2O = 1.89T-0.20 SK and the study was conducted with 5 treatments *viz.,*

1. 100 % RDF (control);
2. Soil Test based recommendation for targeted yield at 5 t/ha (STTY for 5t/ha);

3. Soil Test based recommendation for targeted yield at 6 t/ha (STTY for 6t/ha);
4. Soil Test based recommendation for targeted yield at 7 t/ha (STTY for 7 t/ha); and
5. 30% change on soil value (low fertile: 30% higher than RDF, medium

Fertility : RDF , High fertility : 30 % lesser than RDF).

The fertilizers were applied as per the treatments. The nitrogen was applied in the form of urea, phosphorus in the form of SSP, and potassium in the form of MOP. Nitrogen was applied in three splits at basal, tillering and at panicle initiation stages. SSP was applied as basal and potassium applied in two splits at basal and at panicle initiation stage. The whole plant samples were collected at flowering stage and analysed for nutrient status using standard procedures. The crop was harvested at physiological maturity and the yield components were computed using the standard procedures. The data was statistically analysed by following standard statistical methods (Panse and Sukhatme 1978).

RESULTS AND DISCUSSION

Yield and nutrient uptake

The number of panicles/m^2 and the number of grains/panicle were significantly low in the control than STTY for 7t/ha. On an average, 1000 grain weight was significantly lower in control than STTY for 7 and STTY for 6 t/ha treatments. It is clear from these results that excess fertilizer (above the required amount for a target yield of 7t/ha) had negative effect on promoting the yield. The yield obtained with STTY for 7 t/ha (5.4 t/ha) was higher than the recommended dose of fertilisers. Therefore, the nutritional method was successful in determining the amount of fertilizer required. Yield response in Kg per kg fertilizer use was higher in the treatment STTY for 7 t/ha followed by STTY 6 t/ha. The available nutrient status in soil after harvesting of paddy was recorded more in the STTY for 7t/ha plots. Rama murthy *et al.* (2009) also suggested that soil-based fertilizer recommendations should be preferred to achieve precision in farming and to maximize crop production with minimized fertilizer misapplication for maintaining soil health.

Table 1. Effect of soil test based targeted yield fertilizer recommendation on yield attributes, yield, nutrient uptake and yield response of fertilisers (average data for 3 years)

Treatments	No. of panicles /m^2	No. of filled grains/ panicle	1000 grain wt	Grain yield (t/ha)	Straw yield	N uptake (kg/ha)	P uptake (kg/ha)	K uptake (kg/ha)
100%RDF	567	66	16	4.00	5.00	49.80	16.23	18.20
STTY for 5t/ha	570	69	17	4.30	5.29	55.90	17.65	19.80
STTY for 6t/ha	579	78	18	4.71	5.89	56.78	18.72	20.15
STTY for 7t/ha	608	88	20	5.20	6.52	57.25	19.10	20.68
30%change on soil test value	567	68	16	4.11	5.14	53.17	17.25	18.79
S.Em	14.80	3.00	0.60	0.16	0.21	2.10	0.70	0.85
C.D. (0.05)	42.00	8.90	1.80	0.45	0.62	6.40	2.10	2.56
CV %	11.40	10.40	10.8	11.00	10.30	11.00	10.67	10.60

Table 2. Effect of soil test based targeted yield fertilizer recommendation on physico-chemical properties of soil at harvest of the 2010 season paddy crop end of the experiment

Treatments	pH	EC (dS m^{-1})	OC (%)	Avail. N (kg /ha)	Avail. P_2O_5 (kg /ha)	Avail. K_2O (kg /ha)	Fertilizer dose $N:P_2O_5:K_2O$	Yield response in kg kg^{-1} fertilizer use
Initial status	7.68	0.195	0.60	240	29	290	80 :60 : 50	---
100 % RDF	7.80	0.236	0.72	280	32	290	71 : 48 :48	1.4
STTY for 5 t/ha	7.70	0.210	0.68	260	34	294	68 : 46: 46	2.8
STTY for 6 t/ha	7.65	0.214	0.74	288	33	299	65 : 44 : 45	4.32
STTY for 7 t/ha	7.58	0.200	0.80	297	35	312	104 : 60 : 35	1.45
30 % change on soil value	7.48	0.198	0.69	278	32	292	-----	----
S.Em	7.58	0.206	0.61	266	33	292	-----	-----
C.D. (0.05)	NS	NS	0.05	15	3.9	21.2	-----	-----
CV (%)	8.2	8.9	7.9	8.9	10.2	11.0	-----	-----

Soil characteristics for determining the adequate amount of fertilizers

The highest uptake of NPK was recorded with the targeted yield of 7 t/ha. The same results were in confirmation with the findings of Berar *et al.* (2006). Gracia (1996); Zennow (1998 'a' or 'b' or 'c') Ray *et al.* (2000) reported that prescription-based fertilizer application on testing of soils was more profitable than ad hoc recommendation. The percent achievement of targets aimed at different level was more than 90%, indicating soil test based fertilizer recommendation approach was economically viable within the agro-ecological zone with relatively uniform cropping practices and socio-economic conditions as reported by Berar *et al.* (2006).

CONCLUSION

In north coastal zone the quantity of fertilizers applied to direct sown rice oftenly that exceeds the nutrients required. The balanced nutritional method is useful in determining the appropriate amount of fertilizer to be applied in order to produce the maximum rice yield with the minimum cost on fertilizers. This study showed that the balanced fertilization for targeted yield of 7 t/ha was most beneficial for direct sown paddy in sandy loam soils. Fertiliser dose of 65: 44: 45 kg/ha N+P +K was found to be essential to harvest an yield of 7 t/ha in direct sown paddy.

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Productivity, economics and energetics of wheat under different methods of crop establishment and irrigation schedules

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ABSTRACT

A field experiment was conducted to study the influence of methods of sowing and irrigation schedules on productivity, economics and energetics of wheat, during 2005-06 and 2006-07. The experiment was laid out in split-plot design, with three methods of crop establishment i. e. conventional, bed planting and zero-till in main plots and three irrigation schedules viz. 1.25, 1.00, and 0.75 IW:CPE in sub plots with four replications. The grain yield of wheat did not vary significantly with different methods of crop establishment. However, zero-till sowing was found to be more remunerative in terms of net returns, benefit: cost and specific energy over conventional and bed planting. Among the irrigation schedules maximum grain yield (48.2 q/ha) was obtained when irrigation applied at 1.25 IW: CPE, which was statistically at par with 1.0 IW: CPE (46.8 q/ha), but both were significantly better than irrigation applied at 0.75 IW: CPE (43.7 q/ha). Similar trend was observed for net returns and benefit: cost, while reverse was true for economic water productivity. Maximum energy output (70854 MJ/ha) was recorded with irrigation scheduling at 1.25 IW: CPE followed by 1.0 (68796 MJ/ha) and least in 0.75 (64239 MJ/ha) IW: CPE. However, energy input was the lowest (12225 MJ/ha) in irrigation schedule of 0.75 IW: CPE, which was 18.8 and 13.8 per cent less than irrigation schedules of 1.25 and 1.0 IW: CPE, respectively.

Key words : Economics, energy use efficiency, productivity, specific energy, wheat.

Wheat an energy rich winter cereal contributes 35.5 per cent to the food grain basket of the country with a production of 85.9 million tonnes (Anonymous, 2011). It fits well in different cropping systems involving paddy, maize, cotton, soybean, moong, groundnut and sugarcane etc. In Punjab wheat is grown after rice on about 70 per cent of the total cropped area of the state. The quantum of tillage for wheat cultivation is of paramount importance in rice-wheat system because of 15-20 days turnaround between rice harvesting and timely sowing of wheat crop, which puts tremendous pressure on farmers for expediting seed bed preparation. The delayed sowing and poor seed bed affect germination, growth and ultimately the crop yield (Ball, 1989). Moreover, conventional wheat sowing is time, labour and energy intensive operation which in turn results in further delay in wheat sowing and hence poor plant growth and crop yield (Fujisaka *et al.* 1994; Hobbs *et al.* 1997). Zero tillage technology in contrast to conventional tillage ensures early sowing of wheat, saving in irrigation water and reduces the cost of cultivation (Hobbs *et al.* 1997). Moreover, bed planting system is also gaining importance over conventional system, due to better irrigation management, increased availability of nutrients to crop roots, increased water use efficiency, better weed management through interbed cultivation and less compaction. The bed planting system also facilitates better light penetration within the canopy, reduces crop lodging and requires lesser seed rate. Since, tillage affects moisture retention capacity of the soil, which is one of the most important factors for crop growth. The productivity of wheat also depends largely on the prevailing weather conditions and soil moisture regimes during crop growth period. The soil moisture regimes and prevailing temperature interact to influence growth, development and productivity of wheat. Adequate soil moisture is required for normal development of wheat crop at all the growth stages, which can be obtained by better scheduling of irrigation along with different methods of planting. Thus, methods of sowing and irrigation scheduling have great bearing on prevailing moisture regime and grain yield of wheat. Furthermore, energy input and cost of seed bed preparation also vary under different methods of sowing, which ultimately influence the net returns per unit area. Keeping in view the above facts the present investigation was planned to study the influence of methods of sowing and irrigation schedules on productivity, economics and energetics of wheat.

MATERIALS AND METHODS

A field experiment was conducted at the Students' Research Farm, Department of Agronomy, Punjab Agricultural University, Ludhiana, during 2005-06 and 2006-07. The experimental site is situated at 30° 56' N latitude, 75° 52' E longitude and at an altitude of 247 m above mean sea level in trans-gangetic agro-climatic zone. The soil of the experimental site was loamy sand in texture with normal reaction and electrical conductivity, low in organic carbon, available nitrogen, medium in available phosphorus and potassium. The field capacity and permanent wilting point of 0-180 cm soil profile were 36.89 cm and 11.88 cm, respectively with an average bulk density of 1.63 g cm^{-3}. The experiment was laid out in split-plot design keeping three methods of crop establishment (Conventional, bed planting and zero-till) in main plots and three irrigation schedules (1.25, 1.00, and 0.75 IW:CPE) in sub-plots with four replications. The sowing of wheat crop was done after pre sowing irrigation with tractor drawn zero-till and seed-cum-fertilizer drill using 100 kg seed per hectare and with tractor drawn bed planter (2 rows bed^{-1}) using 75 kg seed per hectare as per the treatment. The irrigation was applied based on IW:CPE as per the treatment keeping 7.5 cm depth for conventional and zero till sown crop and 5.0 cm for bed planted crop. Total irrigation water applied during crop growth season was obtained by multiplying the depth of each irrigation to total number of irrigation applied. The recommended dose of N (120 kg/ha), P_2O_5 (60 kg/ha) and K_2O (30 kg/ha) were applied through urea, DAP and MOP, respectively. Half the doses of N and whole P_2O_5 and K_2O were applied at the time of sowing, while the remaining half dose of N was applied after first irrigation. Topik 15 WP @ 400 g/ha followed by Algrip @ 25 g/ha was applied as post emergence (35 days after sowing) to control the grassy and broadleaf weeds, respectively. The energy input and output were calculated for each item of operations taking standard energy constants as suggested by Panesar and Bhatnagar (1994). Energy use efficiency was calculated by dividing the output energy with input. The specific energy (MJ/q) to produce each quintal of grain was calculated by dividing energy input to corresponding grain yield (Verma *et al.*, 1997). Economic water productivity (Rs/ha-cm) was calculated by dividing the net returns to corresponding irrigation water applied.

RESULTS AND DISCUSSION

Productivity and economics

Pooled data of two years study reveal that grain yield of wheat was not significantly influenced by different methods of crop establishment (Table 1). The maximum grain yield (47.0 q/ha) was recorded in conventionally sown crop, which was closely followed by bed planting (46.3 q/ha) and zero-till (45.3 q/ha) sown crop. Tripathi *et al.* (1999) also observed non-significant differences in grain yield of wheat with conventional, reduced and zero-till planting systems, though the maximum grain yield was realized with conventional sowing. However, applied irrigation water was 2.5 cm less in bed planting system as compared to conventional and zero-till sowing because the irrigation depth in bed planting was 5.0 cm as compared to 7.5 cm in both zero-till and conventional sowing. Aggarwal and Goswami (2003) also observed 3.6 cm saving of irrigation water in bed planted wheat over conventional sowing. This explains the highest economic water productivity (758 Rs/ha-cm) in bed planting than zero-till (724 Rs/ha-cm) or conventionally (710 Rs/ha-cm) sown crop. However, net return and

Table 1. Productivity and economic analysis of wheat as affected by methods of crop establishment and irrigation schedules

Treatment	Grain yield (q/ha)	Irrigation water applied (cm)	Variable cost (Rs ha^{-1})	Net Returns (Rs ha^{-1})	Benefit: Cost	Economic water productivity (Rs/ha-cm)
Method of sowing						
Conventional	47.0	32.5	13408	23063	1.72	710
Bed planting	46.3	30.0	13155	22745	1.73	758
Zero till	45.3	32.5	11654	23544	2.02	724
CD (p=0.05)	NS	-				
Irrigation schedule						
1.25 IW:CPE	48.2	36.6	12755	24645	1.93	673
1.00 IW:CPE	46.8	32.5	12746	23572	1.85	725
0.75 IW:CPE	43.7	25.8	12725	21168	1.66	820
CD (p=0.05)	2.0	-				

benefit : cost were maximum under zero-till (Rs 23544 and 2.02) followed by conventional (Rs 23063 and 1.72) and bed planted (Rs 22745 and 1.73) crop. This was due to lowest variable cost (Rs 11654/ha) in zero-till than bed planting (Rs 13155/ha) and conventional (Rs 13408/ha) sowing. Sharma *et al.* (2002) also reported greater benefit: cost and net returns with zero-till over convention sowing in wheat.

Among the irrigation schedules maximum grain yield (48.2 q/ha) was obtained when irrigation applied at 1.25 IW: CPE, which was statistically at par with 1.0 IW: CPE (46.8 q/ha) but both were significantly better than irrigation applied at 0.75 IW: CPE (43.7 q/ha). Similar trend was also observed for net returns and benefit: cost, however the reverse trend was true for economic water productivity. The highest economic water productivity was obtained with irrigation at 0.75 IW: CPE, which resulted in 6.7 and 10.8 cm less applied water than irrigation scheduling at 1.00 and 1.25 IW: CPE, respectively. Thus, it can be concluded that wheat can be irrigated with 1.0 IW: CPE to get maximum productivity and at 0.75 IW: CPE to get maximum returns per unit of irrigation water.

Energetics

Conventionally sown wheat resulted in maximum energy output (69090 MJ/ha), which was closely followed by bed planting (68061 MJ/ha), but both gave 2499 and 1470 MJ/ha more energy output than zero-till sowing, respectively (Table 2). However, greater energy use efficiency was observed in zero-till sown crop (5.25) as compared to conventional (4.85) and bed planted crop (4.95). The higher energy use efficiency in zero-till was because of no energy utilization during seed bed preparation, while conventional and bed planting consumed high energy during this operation. Similarly, zero-till sowing required 8.2 and 6.1 per cent less specific energy (MJ/q) to produce each quintal of wheat as compared to conventional and bed planting, respectively.

Wheat crop raised with irrigation scheduling at 1.25 IW: CPE gave maximum energy output (70854 MJ/ha), which was followed by 1.0 (68796 MJ/ha) and 0.75 (64239 MJ/ha) irrigation schedules. However, energy input was the lowest (12225 MJ/ha) in irrigation schedule of 0.75 IW: CPE, which was 18.8 and 13.8 per cent less than irrigation schedules of 1.25 and 1.0 IW: CPE, respectively. The lowest energy input under irrigation schedule of 0.75 IW: CPE resulted in higher energy use efficiency and lower specific energy requirement to produce each quintal of wheat grain than irrigation schedules of 1.0 and 1.25 IW:CPE.

Table 2. Wheat energetic as influenced by method of crop establishment and irrigation schedule.

Treatment	Energy input (MJ/ha)	Energy output (MJ/ha)	Energy use efficiency	Specific energy (MJ/q)
Method of sowing				
Conventional	14241	69090	4.85	303
Bed planting	13743	68061	4.95	297
Zero till	12692	66591	5.25	280
Irrigation schedule				
1.25 IW:CPE	14527	70854	4.88	301
1.00 IW:CPE	13917	68796	4.94	297
0.75 IW:CPE	12225	64239	5.25	280

CONCLUSION

All the three methods of crop establishment gave statistically same grain yield however, zero-till sowing was found to be more remunerative for net returns, benefit: cost and specific energy than conventional and bed planting. Wheat should be irrigated at 1.0 IW: CPE to obtain maximum grain yield per unit area and at 0.75 IW: CPE to get maximum returns per unit of irrigation water applied and energy use efficiency.

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Soil-site suitability evaluation for maize crop in Aravalli landscape of Banswara district, Rajasthan

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ABSTRACT

The major soils of Banswara district in Rajasthan were evaluated for their suitability for maize cultivation using limitation method regarding number and intensity of limitations. The study suggests that maize is highly suitable in soils of Pedon P9 but moderately suitable in soils of Pedon P4, P7 and Pedon P8. Whereas soils of Pedon P1, P2 and Pedon P6 are marginally suitable and soils of pedon P3 and Pedon P5 are not suitable for maize cultivation. Soil depth, drainage, erosion and organic carbon are the major limitations for crop growth in the most of soils of Aravalli landscape. The suitability classes can be improved if the correctable limitations (soil fertility characteristics) are altered through soil amelioration measures.

Key words : Soil-site suitability, Banswara, Aravalli landscape, limitations, maize.

Maize is a major food grain crop in the tribal dominated district of Banswara in the Southern Rajasthan and is mostly grown as rain fed crop in different soils associated with varying depth and clay content. However, growing the crop without proper consideration of soil and site properties has resulted in overall lower yield and deterioration of soil health. Moreover, researche on maize is mainly confined to studies related to morphological, varietals improvement and crop management. While, soil survey, classification and mapping of soils, help in understanding the soils potential and suitability for crop planning. Several workers have worked out the suitability of soils for various crop such as cotton (Sehgal, 1991; Kharche and Gaikawad, 1993; Mandal *et al.* 2002), wheat (Sharma and Sharma, 1991; Bhaskar *et al.* 1996; Sharma 1999), sorghum (Pakhan *et al.* 2010) and rubber (Kharche *et al.* 1995). However, such information on soils of Banswara district of Rajasthan is very scanty hence, in view of this, the present study was undertaken to evaluate soil-site suitability for maize crop in Aravalli landscape in Banswara district of Rajasthan.

MATERIALS AND METHODS

The study area lies between 23° 10' and 23° 31' N latitude and 73° and 74° 39' E longitude. The geology of the area comprises mainly of quartzite- schists. The climate of the area is sub-humid tropical and is characterized by hot and dry in summers and cool in winters. The mean annual temperature is 26.75°C and the mean summer and mean winter temperature is 42°C and 10.3°C, respectively. The temperature regime is hyperthermic. The mean annual rainfall is 972 mm, of which about 90-95 per cent is received during June to September. The soil moisture regime is ustic.

Based on the information generated during the SRM of Rajasthan (Shyampura and Sehgal, 1995), seven physiographic units *viz.* hill top, ridge steeply sloping, undulating land (rolling land), undulating pediment, gently sloping narrow valley, very gently sloping pediment plain and very gently sloping valley were selected for the study. Nine pedons representing each physiographic unit were studied. Horizon-wise soil samples were collected from all the pedons for the analysis of physico-chemical properties. Morphological characteristics of the soils were studied as per the procedure outlined in Soil Survey Manual (Soil Survey Staff 1951). Physical and chemical properties were determined by Piper (1950), Jackson (1958) and Sharma *et al.* (1987). The soil site suitability for maize was carried out using the FAO (1976) and Sys *et al.* (1991) land suitability system. The evaluation procedure consisted of three phases viz. identification of soil-site characteristics, determination of crop growth requirements (climate, soils and physiographic) and matching corresponding environment parameters. The soils with no or only slight limitations were grouped under highly suitable class (S1); the soils with more than four slight limitations, and /or with more than three moderate limitations under moderately suitability class (S2); the soil with more than three moderate limitations, and/or one or more severe limitation (s) under marginally suitable class (S3); the soils with very severe limitations which can be corrected under N1 (currently not suitable); the soil with very severe limitations which can not be corrected were grouped under unsuitable class N2 (Sys *et al.*, 1991). This method also identifies the dominant limitations that restrict the crop growth in the sub-class symbol such as climatic (c), topographic (t), wetness (w), physical soil characteristics (s). soil fertility (f) and soil salinity/alkalinity (n). The suitability classes and sub-classes were decided by the most limiting soil characteristics (Table 3).

Soil site parameters were expressed in terms of degree of limitation (0-4). The landscape and soil requirements for maize crop were matched with generated data at different limitation level: no (0), slight (1), moderate (2), severe (3), very severe (4). The number and degrees of limitations suggested the suitability class of pedon for a particular crop (Sys *et al.* 1991). The potential land suitability (Table 3) sub-classes were determined after considering the improvement measures to correct these limitations (Sys *et al.* 1991). Suitability classes were determined with regards to the number and intensity of limitations. Limitations are the deviations from the optimum conditions of the land characteristics which may adversely affect the kind of land use. If land characteristics are optimal for plant growth then it has no limitation. On the other hand when the same characteristics were unfavorable for plant growth then it had the severe limitation. Thus, the evaluation was done by comparing land characteristics with the level of limitations.

RESULTS AND DISCUSSION

The relevant soil characteristics are given in Table 1 and the site and weighted means of soil characteristics are given in Table 2. The soils are developed from granite-gneiss. The kind and degree of limitations of the soils for the maize crop are presented in Table 3. Pedon P1 and Pedon P2 are marginally suitable for maize (Table 3). The major limitations are wetness (drainage), physical soil characteristics (slope and texture) and soil fertility characteristics (CEC). Slope and drainage are the major limiting factor for maize cultivation because they do not allow maintaining soil moisture so, the drainage and slope in soils can be improved by the soil and water conservation measures. The Pedon P3 and Pedon P5 are not suitable for maize cultivation on account of excessive slope, severe erosion, shallow depth, low AWC and poor fertility. The shallow depth of the soil and the excessive slope make them unfit for maize cultivation and therefore, should be under natural vegetation with proper soil and water conservation practices like contour and stone banding to prevent further degradation. Pedon P4 is moderately suitable for maize cultivation. The major limitation include drainage and soil fertility (organic carbon). The suitability of Pedon P4 can be raised and maintained by the proper drainage, application of farmyard manure, green manuring and inclusion of legumes in rotation. Pedon P6 is marginally suitable for maize due to excessive slope, soil depth, drainage and poor fertility. However, these soils can be upgraded to moderately suitable with fertilizer and irrigation management practices. Pedon P7 and Pedon P8 are the moderately suitable for maize cultivation. The major limitations include drainage, slope, soil

Table 1. Climate, site and soil characteristics of Banswara district

	Pedon 1	Pedon 2	Pedon 3	Pedon 4	Pedon 5	Pedon 6	Pedon 7	Pedon 8	Pedon 9
Total rainfall (mm)	700	700	700	700	700	700	700	700	700
Mean temperature (°C)	26.75	26.75	26.75	26.75	26.75	26.75	26.75	26.75	26.75
Mean Max. temperature (°C)	42	42	42	42	42	42	42	42	42
Mean Min. temperature (°C)	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3	10.3
Mean relative humidity (%)	57	57	57	57	57	57	57	57	57
Site characteristics									
Slope (%)	8 to 15	15 to 30	15 to 30	3 to 8	30 to 50	8 to 15	3 to 8	1 to 3	1 to 3
Erosion	e3	e3	e4	e2	e4	e3	e2	e2	e2
Drainage class	D6	D6	D7	D6	D5	D6	D6	D5	D5
Soil characteristics									
Texture	sl	cl	cl	cl	scl	sl	cl	cl	cl
Clay (%)	12.90	36.48	30.15	30.72	10.95	15.25	28.09	24.78	30.60
Depth (cm)	74	37	18	120	150	110	65	65	90
CaCO3 (g Kg^{-1})	21.03	26.89	21.00	17.13	142.86	11.50	20.40	16.95	33.96
Coarse fragment	10-70	40-60	50-60	15-50	NIL	40-80	NIL	NIL	NIL
Soil fertility									
CEC Cmol (p+) Kg^{-1}	8.14	20.75	18.60	19.24	15.33	10.70	15.88	13.99	19.29
Base saturation (%)	91.14	95.14	92.47	96.10	97.65	95.48	96.09	94.84	96.46
NPK rating	LLM	LLM	LLM	LMM	LLM	LLH	LLM	LLH	LLM
ESP	2.90	1.81	2.41	2.72	2.00	3.15	3.20	3.24	2.82
pH	6.85	7.38	7.10	7.67	7.69	6.94	7.83	7.19	6.89

Erosion: e2- moderate; e3- severe; e4- very severe.

Drainage: D5- well drained; D6- some what extreme; D7- extreme drained.

Texture: sl- sandyloam; cl- clayloam; scl- sandyclayloam.

Table 2. Important physico-chemical properties of the soils

	Depth (cm)	Silt (%)	Clay (%)	pH (1:2)	EC (dSm^{-1})	OC (%)	CaCO3 (%)	CEC Cmol (p+) Kg^{-1}
Pedon 1	74	12.08-19.54 (14.65)	10.80-15.67 (12.90)	6.8-6.9 (6.85)	0.28-0.42 (0.32)	0.31-0.64 (0.42)	13.40-29.30 (21.03)	6.10-9.70 (8.14)
Pedon 2	37	22.24-22.67 (22.41)	33.18-38.73 (36.48)	7.2-7.5 (7.38)	0.51-0.65 (0.56)	0.91-1.20 (1.02)	21.60-30.50 (26.89)	17.60-22.90 (20.75)
Pedon 3	18	26.77 (26.77)	30.15 (30.15)	7.1 (7.1)	0.19 (0.19)	1.26 (1.26)	21.00 (21.00)	18.60 (18.60)
Pedon 4	120	23.49-28.84 (26.01)	28.35-37.71 (30.72)	7.5-7.8 (7.65)	0.19-0.38 (0.28)	0.40-0.64 (0.47)	12.50-21.40 (17.13)	15.90-21.10 (19.24)
Pedon 5	150	18.65-23.17 (20.37)	15.57-24.86 (10.95)	7.4-7.8 (7.69)	0.31-0.39 (0.34)	0.22-0.55 (0.32)	75.40-171.0 (142.86)	7.50-18.40 (15.33)
Pedon 6	110	16.29-21.15 (19.77)	12.09-17.12 (15.25)	6.8-7.1 (6.94)	0.34-0.73 (0.54)	0.43-0.45 (0.56)	8.20-13.80 (11.50)	7.70-12.60 (10.70)
Pedon 7	65	15.26-27.35 (21.66)	20.85-37.18 (28.09)	7.6-8.0 (7.83)	0.22-0.39 (0.29)	0.30-0.61 (0.51)	16.70-23.20 (20.40)	12.40-18.10 (15.88)
Pedon 8	65	24.38-26.63 (25.67)	16.21-32.43 (24.78)	7.1-7.2 (7.19)	0.35-0.53 (0.40)	0.34-0.76 (0.50)	11.20-29.10 (16.95)	9.50-18.40 (13.99)
Pedon 9	90	25.59-31.42 (27.91)	17.47-39.17 (30.60)	6.7-7.2 (6.89)	0.20-0.40 (0.30)	0.37-0.55 (0.49)	20.80-42.90 (33.96)	8.70-24.60 (19.29)

Figures in parentheses indicate corrected weighted mean values.

Table 3. Limitation levels of the land characteristics and land suitability classes for maize

Pedon	Wetness (w) Drainage	Texture	Slope (%)	Soil depth (cm)	$CaCO_3$ (%)	CEC Cmol (p+) Kg^{-1}	ESP	pH 1:2)	OC (%)	Actual land suitability subclass	Potential land suitability sub class
P1	3	1	1	1	0	2	0	0	2	S3f,s,w	S2s
P2	2	0	2	3	0	0	0	0	1	S3f,s,w	S2s
P3	2	0	4	4	0	0	0	0	0	N2s,w	-
P4	2	0	1	0	0	0	0	0	2	S2f,s,w	S2s
P5	0	0	4	0	0	0	0	0	2	N2s,f	-
P6	2	3	2	0	0	2	0	0	1	S3f,s,w	S2s
P7	2	0	1	1	0	2	0	0	1	S2f,s,w	S2s
P8	0	0	0	1	0	2	0	0	2	S2f,s	S2s
P9	0	0	0	0	0	0	0	0	1	S1f	S1

Limitation: 0-no slight; 1- slight; 2- moderate; 3- severe; 4- very severe

Suitability subclasses: f- soil fertility limitations; s- physical soil limitations; w-wetness limitations depth, organic carbon and CEC. These soils required proper drainage, application of organic manures and nitrogenous fertilizers. Pedon P9 is highly suitable for maize cultivation due to having no limitations of wetness (drainage), slope, texture, soil depth. Only having slight limitation of organic carbon and so, the organic carbon status in these soils can be improved by the addition of farmyard manure and green manuring.

The pedon P1, P2, and P6 are marginally suitable for maize whereas pedons P4, P7 and P8 are moderately suitable. These findings are in conformity with the finding of Leelavati *et al.* (2010) who noticed that the soils of Yerpedu mandal of Chittoor district were moderately suitable for growing maize in Andhra Pradesh. The Pedon P9 is highly suitable for maize crop, while Pedon P3 and P5 are not suitable for maize crop due to excessive slope, severe erosion, shallow depth, low AWC and poor fertility. These findings are corroborated with the finding of Satyavathi *et al.* (2004) who indicated that soil fertility characteristics viz. pH, organic carbon and physical soil characteristics like texture and soil depth are the limitations for maize cultivation in the Telangana Region of Andhra Pradesh.

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Effect of nitrogen on growth, yield and quality of fodder pearl millet (*Pennisetum glaucum*) cultivars under irrigated condition of North-Western Rajasthan

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In India, the requirement of green fodder was 611.99 Mt against the availability of only 224.08 Mt (Anonymous. 2006). It reflects a wide gap between demand and supply because the regional deficit are more important than the national deficit especially for forages which account only 3.4 m ha and 9.3 m ha area of total cultivable land is utilized for forage production in 1999 in Rajasthan and India, respectively (GOI, 2004). This is because of increasing pressure of human population on land in the country as a result of which top priority is given to only grain crops, preferential use of low-capability land for forages and multiplication ratio is very narrow in most of fodders. The efficiency of milch as well as drought animals largely depends upon the supply of quantity and quality of ration in which green fodder plays a vital role. In the recent years shortage of fodder has remained the burning problem, which calls for the attention of researchers to initiate efforts that can ensure regular fodder supply for development of dairy farming and improvement of the cattle wealth. These are following objectives of study

i. To study the effect of nitrogen on growth, yield and quality of fodder pearl millet cultivars

ii. To identify suitable cultivar of fodder pearl millet

iii. To find out optimum dose of nitrogen for fodder pearl millet

The field experiment was conducted at the Agronomy farm, College of Agriculture, Bikaner during the *kharif* season of 2007. The farm situated at 28.01°N latitude and 73.22°E longitude at an altitude of 234.70 metres above mean sea level. Bikaner falls under Agro-ecological region No. 2 under arid ecosystem (Hot Arid Eco-region with desert and Saline soil). PET in this region ranges between 1500-2000 mm. Bikaner has arid climate and annual rainfall ranges between 200 to 300 mm.

During summers the maximum temperature may go as high as 48°C, while in the winters it may fall as low as 0°C. The periodical mean weekly weather parameters for the period of the experimentation recorded from the meteorological observatory show that lowest and highest maximum temperature of 35.4°C and 39.2°C were recorded in the 39th and 29th standard meteorological week, respectively. Likewise values of minimum temperature (22°C & 27.8°C) were recorded in the 39th and 29th standard meteorological weeks, respectively during the crop growing period. The experimental field was loamy sand in texture, slightly alkaline in reaction (pH 8.36), poor in organic carbon (0.07%), low in available nitrogen (88.25 kg/ha) and medium in P_2O_5 (23.80 kg/ha) and K_2O (169.0 kg/ha). The experiment was laid out in split plot design with three replications assigning twenty treatments consisting of four varieties viz., "Rajasthan Bajra chari-2", "Pusa Bajra-266", "Raj-171" and "Giant Bajra" in main plots and five levels of nitrogen viz., control, 40, 80, 120 and 160 kg/ha in subplots. The seed of different varieties of fodder pearl millet were sown @ 10 kg/ha in lines spaced at 30 cm on 17 July, 2007 by "*kera*" method in open furrows.

Table 1. Effect of varieties and nitrogen levels on growth parameters and yield of fodder pearl millet cultivars

Treatments	Plant height (cm)	Dry matter (g/plant)	Tillers/ plant	Yield (t /ha)	
				Green fodder	Dry fodder
Varieties					
"Rajasthan Bajra chari-2"	178.9	32.0	5.4	39.79	10.07
"Pusa Bajra - 266"	131.6	18.6	3.7	29.44	5.53
"Raj-171"	144.4	21.7	4.1	33.03	6.94
"Giant Bajra"	160.2	26.1	4.8	36.43	8.10
SEm ±	3.66	0.99	0.08	0.767	0.20
CD (P=0.05)	12.7	3.44	0.27	2.65	0.66
Nitrogen level (kg/ha)					
0	134.0	13.6	4.0	29.16	6.68
40	145.3	20.3	4.3	32.09	7.26
80	155.8	25.9	4.6	35.17	7.75
120	165.9	30.7	4.8	37.92	8.22
160	168.0	33.2	4.9	39.01	8.38
SEm ±	3.23	1.09	0.08	0.869	0.161
CD (P=0.05)	9.32	3.13	0.24	2.5	0.465

Plant height and dry matter accumulation at different growth stages was significantly higher in "Rajasthan Bajra chari-2" than other varieties. This may be due to inherent genetic character of variety. These findings are in concurrence with AICRP-Forage Crops (2006). Application of nitrogen @ 120 kg/ha which was statistically at par with the 160 kg N/ ha significantly increased plant height and dry matter accumulation at different growth stages over control, 40 and 80 kg N/ha. It might be due to that nitrogen has in plant life, its role in rapid multiplication of tissues and increase in amount of growth substances such as naturally occurring photo hormones, photosynthesis rate, increase in auxin supply and with higher level of nitrogen might have brought about a significant increase in plant height, dry matter accumulation and number of tillers per plant. The response of nitrogen fertilization in terms of improved growth is further supported by the fact that the soil of experiment field was low in available nitrogen (90.25 kg/ha). As a principle, a soil deficient in plant nutrient improves crop growth when supplied with a particular nutrient in question. These results are in conformity with those of Babu *et al.* (1995). "Rajasthan Bajra chari-2" also produced significantly higher number of tillers per plant than other varieties. In case of nitrogen @ 120 kg/ha which was at par with 160 kg N/ha, significantly increased number of tillers per plant over control, 40 and 80 kg N/ha.

Dry matter accumulation was significantly higher in "Rajasthan Bajra chari-2" than other varieties. Application of nitrogen @ 120 kg/ha was statistically at par with 160 kg N/ha, significantly increased dry matter accumulation over control, 40 and 80 kg N/ha at all growth stages.

Green and dry fodder yield were significantly higher in "Rajasthan Bajra chari-2" than "Pusa Bajra-266", "Raj-171" and "Giant Bajra". Application of nitrogen @ 120 kg/ha significantly increased green and dry fodder yields of pearl millet over control, 40 and 80 kg N/ha which was at par with 160 kg N/ha. The fodder yield, being a function of the cumulative effect of growth parameters such as plant height, number of tillers per plant and dry matter accumulation per plant which were higher with 120 kg N/ha, resulting in higher forage yield under this treatment. The increase in fodder yield with increasing level of nitrogen could also be explained by better nutritional condition of the crop as supported by higher nitrogen uptake when fertilized with 120 kg N/ha. More uptake of nutrients by application of nitrogen probably favored better growth and development of crops, resulting into increased fodder yield. These findings corroborate the results of Tiwana *et al.* (2004) and Hooda *et al.* (2004) who found a significant increase in fodder yield with increased levels of nitrogen.

"Rajasthan Bajra chari-2" not only produced maximum yield of pearl millet fodder but also good quality of fodder than other varieties. Crude protein content (%) in dry fodder of variety "Rajasthan Bajra chari-2" was significantly higher than other varieties. This might be due to that higher nitrogen content in this variety. Nitrogen is an integral part of protein as a result higher crude protein found in dry fodder of "Rajasthan Bajra chari-2" than other varieties. The similar results were also obtained by AICRP-Forage Crops (2006) who reported significantly higher crude protein in variety "Rajasthan Bajra chari-2" than rest of varieties. The results are also in agreement with those obtained by AICRP-Forage Crops (2005). "Rajasthan Bajra chari-2" contains significantly higher ether extract (6.73%), mineral matter (12.58%) and significantly lower crude fibre (24.50%) as well as nitrogen free extract (44.74%) proving its better palatability and acceptability for animals as compared to other varieties. This may be due to inherent genetic characters of varieties and higher content of nitrogen which is the major constituent of amino acids and protein (Randawa *et al.* 1989) and decreased the pectin, cellulose, hemicellulose and proportion of carbohydrates and hence decreased crude fibre and nitrogen free extract. These findings are in accordance to the findings of Babu *et al.* (1995), Jakhar *et al.* (2003), Tiwana and Puri (2005). In case of nitrogen @ 120 kg/ha was at par with 160 kg N/ha, significantly increased crude protein content over control, 40 and 80 kg N/ha.

Table 2. **Effect of varieties and nitrogen levels on different quality parameters in fodder pearl millet**

Treatments	Crude protein (%)	Ether extract (%)	Crude fibre (%)	Ash (%)	Nitrogen free extract (%)	Total digestible nutrient (%)
Varieties						
"Rajasthan Bajra chari-2"	11.4	6.7	24.5	12.6	44.74	62.8
"Pusa Bajra - 266"	8.6	5.5	28.8	8.0	49.09	64.8
"Raj-171"	9.6	5.9	26.7	9.6	48.2	64.2
"Giant Bajra"	10.5	6.3	27.5	10.7	45.02	63.6
SEm ±	0.22	0.09	0.15	0.18	0.379	0.13
CD (P=0.05)	0.77	0.31	0.51	0.61	1.31	0.46
Nitrogen level (kg/ha)						
0	8.3	5.5	29.3	7.5	49.4	65.1
40	9.2	5.8	27.8	9.1	48.0	64.3
80	10.3	6.2	26.5	10.5	46.4	63.7
120	11.1	6.5	25.4	11.8	45.1	63.1
160	11.3	6.6	25.2	12.1	44.8	62.9
SEm ±	0.21	0.08	0.23	0.34	0.44	0.27
CD (P=0.05)	0.6	0.24	0.65	0.98	1.25	0.78

Ether extract and mineral matter were significantly higher in "Rajasthan Bajra chari-2" than other varieties. In case of nitrogen @ 120 kg/ha significantly increased ether extract and mineral matter over control, 40 and 80 kg N/ha which was at par with 160 kg N/ha Nitrogen fertilization not only improved the growth and yield of pearl millet fodder but also quality of fodder by increasing the crude protein content. The crude protein increased significantly due to the application of nitrogen up to 120 kg/ha. Application of nitrogen increased the availability of nitrogen, which resulted in significant increase in nitrogen content in fodder and ultimately the crude protein content. These results are in cognizance with the findings of Shivran and Pareek (2001). Significant increase in ether extract of fodder pearl millet was observed up to 120 kg N/ha. Application of nitrogen significantly decreased the crude fiber. This might be due to the fact that nitrogen application increased the uptake of nitrogen which is the constituent of amino acids and protein and decreased the pectin, cellulose and hemicellulose content which are major constituents of fibre (Babu *et al.* 1995). Application of nitrogen up to 120 kg/ha significantly decreased the NFE content of fodder pearl millet. This could be attributed to the fact that nitrogen application at higher doses had significant effect on crude protein content thereby reducing the proportion of carbohydrates and hence decreased NFE content which is in accordance with findings of Jakhar *et al.* (2003). Crude fibre, nitrogen free extract and total digestible nitrogen were significantly lower in "Rajasthan Bajra chari-2" than other varieties. Application of nitrogen @ 120 kg/ha significantly decreased crude fibre, nitrogen free extract and total digestible nutrient over control, 40 and 80 kg N/ha which was at par with 160 kg N/ha. On the basis of one years results of the present investigation, it may be concluded that the cultivar "Raj Bajra Chari-2" along with 120 Kg N/ha application resulted significant increase in growth parameter, yield attributes, green fodder, dry fodder yield. However, these results are only indicative and further experimentation is required at more consistent and definite conclusion for recommendation to the farmers.

Results of the field experiment that "Rajasthan Bajra chari-2" cultivar of pearl millet significantly higher plant height, total numbers of tillers per plant, dry matter accumulation per plant, green and dry fodder yield, crude protein content and ether extract was recorded. However, "Pusa Bajra-266" recorded significantly higher total digestible nutrient, nitrogen free extract and crude fibre. Application of nitrogen up to 120 kg/ha significantly increased the plant height, dry matter accumulation, tillers per plant, green, and dry fodder yield, crude protein, and ether extract which was at par with 160 N kg/ha. However, the crude fibre content, nitrogen free extract and total digestible nutrient were significantly decreased with application of 120 N kg/ha.

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Climate change vis-a-vis Indian agriculture*

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ABSTRACT

Climate change and variability are posing the serious challenges influencing the performance of Indian agriculture. The fourth IPCC report clearly brought out the global and regional impacts of projected climate change on agriculture. India being a large country with diverse agro-climatic regions is more vulnerable in view of huge population dependant on agriculture and poor coping mechanism. There are evidences already of negative impacts on yield of wheat, rice and other crops in parts of India due to increased temperature, increased water stress and reduction in number of rainy days which in turn would result in greater instability in food production. Researchers and policy framers should develop a comprehensive adaptation and mitigation strategies for coping the adverse impact of climate change. Changes in land use management, development of multiple stress tolerant varieties, efficient cropping systems that match with changed rainfall patterns, resource conservation technologies, water harvesting and supplemental irrigation for drought proofing in rainfed areas can help in mitigating the adverse impact of climate change and variability. Alternate land use system like agro-forestry system and other biological carbon capture systems can also help in both adaptation and mitigation. Reliable early warning system of environmental changes and their spatial and temporal magnitude will be of quite help and policies to support the diffusion of this information and to help interpret these forecasts in terms of their agronomic and economic implications are required to help farmers in a big way.

The earth's climate has remained dynamic throughout 4.5 billion years history of the earth, showing changes through a natural cycle periodically. These climate changes in the past geological time had profound influence on sea level, rainfall patterns and temperature related weathering processes. Most of the evidences of past climate change, however, are circumstantial. The combination of a unique level of temperature increase in the late 20th century and improved constraints on the role of natural variability provides further evidence that the greenhouse effect has already established itself above the level of natural variability of the last 1000 years and is greater than the best estimate of global temperature change for the last interglacial period. The global warming potential of carbon dioxide was estimated by the Swedish Chemist Svante Arrhenius and subsequently many researchers concluded that human consumption of fossil fuels was leading to significant increase in atmospheric CO_2 and global average temperature (Callender 1938). Huang *et al.* (2000) have reported 20th century to be the warmest of the past five centuries and later Huang (2004) reported 20th century warming is a continuation to a long-term warming started before the onset of industria-lization. The 4th Assessment Report of IPCC (2007a) has also mentioned that the change in earth's climate has been in an unprecedented manner in the past 40,000 years, but greatly accelerated during the last century, due to rapid industrialization and indiscriminate destruction of natural environment.

Climate change and agriculture are interrelated processes both of which take place on global scale. Global warming is projected to have significant impacts on conditions affecting agriculture, including temperature, CO_2, glacier runoff, precipitation and the interaction of these elements. These condition in term determine the carrying capacities of different ecosystems to produce enough biomass including food for human population and domesticated animals. The overall effect of climate change on agriculture will depend on the balance of these effects. Assessment of the effects of global climate change on agriculture might help to properly anticipate and adapt farming to maximize agricultural production. At the same time, agriculture has been shown to produce significant effects on climate change, primarily through the emission of GHGs as about 12.5% of total emission is from agricultural products globally. Land use change such as deforestation and desertification, together with the use of fossil fuels are the major anthropogenic sources of carbon dioxide.

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*Lead Paper presented in National Seminar on Indian Agriculture : Preparedness for Climate Change.

The various assessment reports brought out since 1990s by the Inter-Governmental Panel on Climate Change (IPCC) have reconfirmed that the global atmospheric concentrations of carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) have increased precedently (Table 1). The increase in green house gases (GHGs) was 70% between 1970 and 2004 and the IPCC has shown through a series of observations and modelling studies that these increases in GHGs have resulted in warming of the climate system by 0.74°C between 1906 and 2008 (Aggarwal, 2006). The Inter-Governmental Panel on Climate Change (IPCC, 2007a) has projected that the temperature increase by the end of this century is expected to be in the range of 1.8-4.0°C and it is also likely that future tropical cyclones will become more intense with larger peak wind speeds and heavier precipitation. Increase in the amount of precipitation are likely in high latitudes while decreases are expected in most sub-tropical land regions, continuing observed patterns in recent trends. The projected sea level rise by the end of this century is likely to be 0.18-0.59 m (Aggarwal, 2008). The IPCC (2007b) has projected 0.50-1.20 °C rise in temperature by 2020, 0.88-3.16 °C by 2050 and 1.56-5.44 °C by 2080 depending upon the scenario of future development in south Asia including India.

The impact of climate change is likely to have a great influence on the agriculture and eventually on the food security and livelihoods of a large section of the rural population. Droughts, floods, tropical cyclones, heavy precipitation events, hot extremes, and heat waves are known to negatively impact agricultural production and the livelihood of the farmers. Further, the global climatic changes will affect agriculture through their direct and indirect effects on crops, soils, livestock and pests. Increase in atmospheric CO_2 promotes growth and productivity of plants with C_3 photosynthetic pathway. Increase in temperature, depending on the current ambient temperature, on the other hand, can reduce crop duration, increase crop respiration rates, affect the survival and distribution of pest populations, hasten nutrient mineralization in soils, decrease fertilizer use efficiency and increase evapotranspiration. It has been projected that 2°C increase in average temperatures would reduce world GDP by roughly 1% (Stern, 2007) and thus climate change ultimately will cause a decrease in annual GDP of 4% in Africa and 5% in India without offsetting the innovations for mitigation of impact of climate change (World Bank, 2009). Easterling *et al.* (2007) reported that food security of most developing countries including India is likely to come vulnerable in the near future with moderate

Table 1. Greenhouse gases level since 1750

Greenhouse gas	**Level**	
	2005	**1750**
Carbon dioxide (CO_2)	379 ppm	280 ppm
Methane (CH_4)	1774 ppb	715 ppb
Nitrous oxide (N_2O)	319 ppb	270 ppb

Source: Aggarwal, 2008

increase in temperature. At the same time, differential impacts of climate change on food production are likely to have consequences on international food prices and trade.

CLIMATE CHANGE AND INDIAN AGRICULTURE

In India, agriculture sector contributes 28% of the total GHGs emissions (Table 2) which are primarily due to enteric fermentation in ruminant animals (59%), methane emission from rice paddies (23%) and nitrous oxides from application of manures and fertilizers to agricultural soils. The emissions from Indian agriculture are likely to increase significantly in future due to our need to increase food production. The latter would require greater emphasis on fertilizers and other inputs which will lead to increased emissions of nitrous oxides and other GHGs. Increase temperatures would lead to higher emissions even at the current level of fertilizers consumption.

Earlier studies conducted in India also generally confirm the trend of agricultural decline with climate change (Aggarwal and Sinha, 1993; Rao and Sinha, 1994; Lal *et al.*, 1998; Saseendran *et al.*, 2000; Aggarwal and Mall, 2002; Mall and Aggarwal, 2002; Aggarwal, 2008). Recently, it has been projected there is a probability of 10-40 loss in crop production in India by 2080-2100 due to global warming (Rosenzweig and Parry, 1994; Fischer *et al.*, 2002; Parry *et al.*, 2004; IPCC, 2007b) despite beneficial aspects of increased CO_2, if adaptation mechanism to encounter climate change is not put in place.

Systematic studies on impact of climate change on crop production in our country are very few, however, some studies have been published on the quantification of impact on different crops in various parts of country by using several methods including simulation models. While most models used for this purpose have been validated at the plot level, few studies have evaluated them for multiple years at a regional level (Carbone *et al.*, 2003). However, estimates of radiative forcing reveal that gases like CO_2 contribute to warming, whereas aerosol and clouds tend to cool the surface leading to the global warming controversy. It is known that climate models do a reasonable job of capturing the large-scale aspects of current climate, but still contain systemic model errors adding uncertainty to the future projection (Annamalai *et al.*, 2011). Hence, the regional model outputs on temperature and rainfall variations have to be handled with caution while using them for impact assessment.

Early studies indicated that significant changes in climate are observed over different regions (Sinha *et al.*, 1998a). The mean air temperatures over the wheat growing regions were high by 1.7 °C over a period of 15 days (January 16 to February 1), the actual temperature rise was 2.3 to 4.5 °C in the major wheat-producing region of Punjab and Haryana (Sinha *et al.*, 1998b). Through these studies they projected the serious effects of regional temperature on productivity of major crops like wheat and rice. Similar, some other research results also indicated that the productivity of rice

Table 2. Contribution of major sectors to emission of GHGs in India

S. No.	Major sectors	Relative emission
		%
1.	Energy	61
2.	Agriculture	28
3.	Industrial processes	8
4.	Wastes and land use change and others	3

Source: NATCOM, 2004

Table 3. Projected changes in climate in India (2070-2099)

Region	January-March	April-June	July - September	October - December
Change in temperature (°C)				
Northeast	4.95	4.11	2.88	4.05
Northwest	4.53	4.25	2.96	4.16
Southeast	4.16	3.21	2.53	3.29
Southwest	3.74	3.07	2.52	3.04
Change in precipitation (%)				
Northeast	-9.3	20.3	21.0	7.5
Northwest	7.2	7.1	27.2	57.0
Southeast	-32.9	29.7	10.9	0.7
Southwest	22.3	32.3	8.8	8.5

Source: Kavikumar (2010)

crop may decline by 41% for 4°C increase in temperature (Lal *et al.*, 1998). However, there are reports indicating that the choice of the variety makes a difference between increase and decrease in the yield while being exposing to climate change scenarios (Challinor *et al.*, 2008). The results of recently published study conducted over the Cauvery basin of Tamil Nadu using PRECIS and RegCM3 regional climate models (RCMs) showed an increasing trend for maximum temperature, minimum temperature and rainfall (Geethalakshmi *et al.*, 2011). Agarwal and Mall (2002) have also reported that 2°C increase in mean temperature has resulted in considerable decrease in grain yield of rice, if there is no adaptation measure taken. Later on Aggarwal (2009) reported that for every 1°C increase in temperature, yields of wheat, soybean, mustard, groundnut and potato are expected to decline by 3-7%. Similarly, rice yields may decline by 6% for every 1°C increase in temperature (Saseendran *et al.*, 2000). IWMI (2007) estimated that for every 1°C rise in mean temperature, there is a corresponding 7% decline in rice yield; similarly, the International Food Policy Research Institute calculates a 12-14% decline in world rice production by 2050 due to the effects climate change (Nelson *et al.*, 2009).

Overall the temperature increase are likely to be much higher during Rabi season than in rainy (*kharif*) season. Precipitation is likely to increase almost in all the months except during December-February when it is likely to decrease. Furthermore, climate change projections made up to 2100 for India indicate an overall increase in temperature by 2-4°C (Table 3) with no substantial change in precipitation (Kavikumar, 2010). At all India level, there is no trend in monsoon rainfall during last 100 years, but there are some regional patterns. Areas of increasing trend in monsoon rainfall are found along the west coast, north Andhra Pradesh and adjoining areas, north east India and parts of Gujarat and Kerala (-6 to -8% of normal over 100 years). The warming trend in India over the gast hundred years (1901-2007) was observed to be 0.51°C with accelerated warming of 0.21°C per every ten years since 1970 (Kumar, 2009).

The spatial distribution of temperature changes indicates a significant warming trend along thewest coast, central India, and interior Peninsula and over northeast India. However, cooling trend has been observed in northwest and some parts in southern India. Instrumental records over the past 130 years do not show any significant long-term trend in the frequencies of large-scale droughts or floods in the summer monsoon season. The frequency of cyclonic storms that form over Bay of Bengal has remained almost constant over the period 1887-1997. The magnitude of impact of climate change is likely to vary to vary in different parts of the country. Parts of western Rajasthan, Southern Gujarat, Madhya Pradesh, Maharashtra, Northern Karnataka, Northern Andhra Pradesh and Southern Bihar are likely to be more vulnerable in terms of extreme events (Mall *et al.*, 2006).

Projections indicate the possibility of loss of 4-5 million tonnes in wheat production with every rise of 1°C temperature throughout the growing period with current land use (Aggarwal, 2008). In March 2004, temperatures were higher in the Indo-Gangetic plains by 3-6°C, which is equivalent to almost 1°C per day over the whole crop season. As a result, wheat crop matured earlier by 10-20 days and wheat production dropped by more than 4 million tonnes in the country (Samra and Singh, 2004). Losses were also significant in other crops, such as mustard, peas, tomatoes, onion, garlic and other vegetable and fruit crops (Samra and Singh, 2003). Similarly, the drought of 2002 led to reduced area coverage of more than 15 m ha of the rainy- season crops and resulted in a loss of more than 10% in food production (Samra and Singh, 2002).

Recent simulation studies has projected adverse impacts on maize yields in *kharif* due to rise in atmospheric temperature; but increased rainfall can partly offset those loses. Spatio-temporal variations in projected changes in temperature and rainfall are likely to lead to differential impacts in the different regions (Byjesh *et al.*, 2010). Analysis on sorghum also indicated that the yield loss due to rise in temperature is likely to be offset by projected increase in rainfall. However, CO_2 enrichment/ fertilization has clearly demonstrated beneficial effect on productivity particularly in C_3 plants. A recent meta-analysis of CO_2 enrichment experiments in fields has shown that enrichment of CO_2 with 550 ppm leads to a benefit of 8-10% in yield in wheat and rice in the field environment (Kumar *et al.*, 2011), up to 15% in soybean, and almost negligible in maize and sorghum (Long *et al.*, 2005); but increase in temperature may alter these results. However, complete amelioration of yield loss beyond 2°C rise may not be attained even after the doubling of rainfall (Srivastava *et al.*, 2010).

Climate change is expected to accelerate the hydrological cycle, which may result into more precipitation mainly due to reduction of glacier size in long term, thus having contrasting impact on water resources. In India, winter precipitation is projected to decline and this is likely to lead to higher need for rabi irrigation, lesser storage and increased water stress during the pre-monsoon months. Intensity of rains is projected to increase, which will imply more frequent and severe floods and lesser recharge to groundwater (Jain, 2012). Further, water for agriculture is becoming increasingly scarce, and climate change-induced higher temperatures will increase crops' water requirements, so shortages will become more serious in coming decades. By 2025, 15-20 million of the world's 79 million hectares of irrigated rice lowlands, which provide three-quarters of the world's rice supply, are expected to suffer some degree of water scarcity (IWMI, 2007). It is also estimated that to eliminate hunger and undernourishment for the world's population by 2025, the additional water requirements may be equivalent to all freshwater withdrawn and used today for agricultural, industrial and domestic purposes (SIWI, 2005).

ADAPTATION AND MITIGATION STRATEGIES

India being a large country with diverse agro-climatic regions, the adaptation and mitigation strategies have to be location specific and cost effective. There is an urgent need to identify adaptation strategies that may anyway be needed for sustainable development of agriculture. Changes in land use management, development of multiple stress tolerant varieties, and evolvement of new agronomic management strategies are some of the adaptation strategies that are being talked about. Suitable resource conservation technologies and proper contingency plans for temperature and rainfall related risks need to be developed. Agro-forestry system and other biological carbon capture systems can also help in reducing the carbon emission. Already large numbers of efficient water and fertilizer management practices are available for paddy cultivation which helps in lower emission of methane and nitrous oxide. Water harvesting and supplemental irrigation for drought proofing areas, improved drainage and flood control measures in high rainfall regions are of immense importance for mitigating the adverse effect of climate change. Similarly, development of knowledge based decision support system for translating weather information into operational management practices required to be put in place as adaptation mechanism. These adaptations can be at the level of individual farmer, society, farm, village, watershed, or at national level. Some of the possible adaptation options are discussed here.

Alternate land-use systems

In the current scenario, agro forestry systems have attracted special attention in climate change mitigation and adaptation discussions as most of these farming systems yield multiple benefits, such as sustainable production, resource conservation, groundwater recharge, employment generation and social equity. Among several solutions being debated to mitigate climate change, sequestration of carbon (C) is one of the key options (Lal, 2011) and agro forestry systems can help ameliorate global climate change by sequestrating carbon in their live biomass as well as in the soil. Several studies have shown that inclusion of trees in the agricultural landscapes often improves the productivity of systems while providing opportunities to create carbon sinks (Maikhuri *et al.*, 2000; Pandey, 2002 & 2007; Albrecht and Kandji, 2003; Jeet Ram *et al.*, 2011). An average carbon storage by agro forestry land use system has been estimated to be around 9, 21, 50 and 63 Mg C ha^{-1} in semi-arid, sub humid, humid and temperate regions, respectively (Schroeder, 1994). Sathey and Ravindranath (1998) estimated 25 t/ha carbon sequestration (on average basis) potential in agro forestry in India. Singh and Lal (2000) have estimated that by bringing 40 m/ha degraded land under forest with 5.5 tonnes/ha, the carbon mitigation of 3.32 Gt would be possible in next 50 years with annual reduction of about 0.072 Gt carbon.

Globally, soil degradation processes affects about 1216 Mha area under moderate level of estimation (Table 4), whereas about 121 million hectare area is under the category of degraded lands in India. Afforestation of these marginal agricultural soils or degraded soils has a large potential of carbon sequestration. Thus, adoption of a restorative land use through agro-forestry and efficient management practices on degraded soils can reduce the rate of enrichment of atmospheric CO_2 while having positive impacts on food security, agro-industries, water quality and the environment.

Agro-forestry for eroded lands

Protection from grazing and afforestation with suitable species are the most effective measures for checking soil erosion and

Table 4. Estimates of soil degradation in world and in India

Process of degradation	World (Mha)*	India (Mha)**
Water erosion	751	82.6
Wind erosion	280	12.4
Chemical degradation	146	24.7
Physical degradation	39	1.1
Total degraded land	1216	120.8

*Estimates of soil degaradation in world at moderate level (Lal, 2004); **NBSS&LUP, 2008 consequently ravine formation. Woody species found growing in eroded habitats may find priority in afforestation program. For example, *Acacia nilotica, A. eburnea, A. leucophloea, A. catechu, Azadirachta indica, Albizzia lebbeck, Balanites roxburghii, Butea monosperma, Dalbergia sissoo, Dendrocalamus strictus, Dichrostachys cineria, Eucalyptus* spp., *Feronia limonia, Pongamia pinna ta, Prosopis julifiora* and *Ziziphus mauritiana* have been found to adapt easily in the ravines of river Yamuna at Agra and Kshipra at Ujjain. Among grasses *Dichanthium annulatum, Cenchrus ciliaris, Bothriochloa pertusa, Chrysopogon fulvus, Themeda triandra, Heteropogon contortus, Sehima nervosum, Tragus biflorus, Iseilema laxum, Cynodon dactylon* and *Saccharum munja* flourish well in ravine lands. After protecting from grazing silvi-pastoral system involving the above-mentioned tree and grass species and introducing legumes such as *Stylosanthes, Alysicarpus, Melilotus,* etc may be developed with great success. High value medicinal species such as *Aloe vera* and *Jatropha curcas* can easily be blended in these habitats. Integrated Watershed Management Programmes are being implemented on a massive scale since 1991, which is most sustainable multipurpose strategy.

Agro-forestry for salt-affected lands

On the basis of experiments conducted on highly alkali soil *Prosopis julifiora, Acacia nilotica, Casuarina equisetifolia, Tamarix articulata, Eucalyptus tereticornis* and *Parkinsonia aculeata* demonstrated a higher tolerance. RamJeet *et al.* (2008) reported 19.22 to 56.5 t/ha air-dry biomass from different species raised on high sodic soil (Fig. 1). The woody species like *Acacia farnesiana, Parkinsonia aculeata* and *Prosopis juliflora* were rated the most tolerant to waterlogged salinity and could be grown satisfactorily on soils with salinity levels up to 50 dS/m in their root transmission zone. Tree species like *Acacia nilotica, A. tortilis, Casuarina glauca, C. obesa* and *C.equisetifolia* could grow on sites with ECe varying from 10-25 dS/m. The biomass of *P. juliflora* and *C. glauca* was the highest (98 and 96 t/ha, respectively) followed by *A. nilotica* (52-67 t/ha) and *A. tortilis* (41 t/ha) when planted with sub surface or furrow techniques proving that these are the most suitable species for saline waterlogged soils.

Combating waterlogging through biodrainage

In waterlogged areas near canals planting cloned *Eucalyptus* on bunds (of - one meter height) on farmers field proved very useful, which not only controlled rise in water table (Fig. 2) but also helped in substantial revenue generation. Farmers harvested 34 t/ha fresh aerial biomass and 12.3 tones root biomass per ha from 5 years and 4 months old plantation. The strip-plantations sequestered 15.5 t/ha

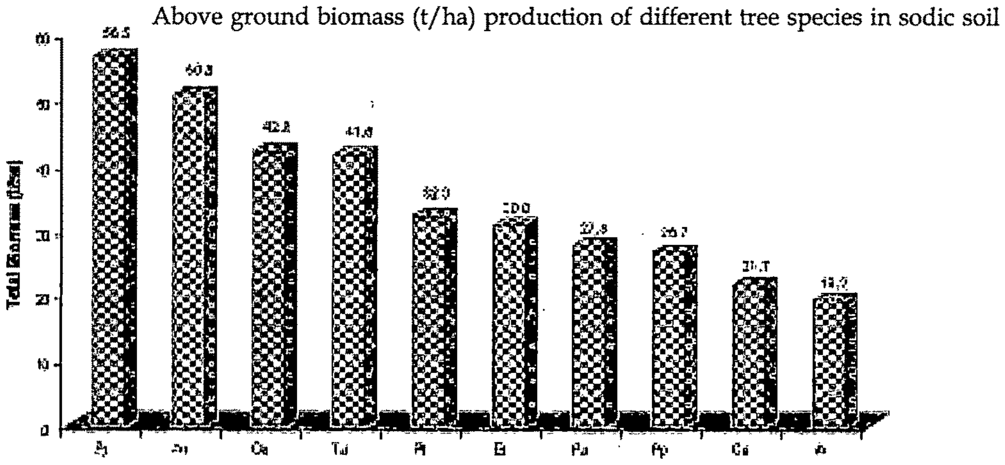
Above ground biomass (t/ha) production of different tree species in sodic soil

Fig. 1. Above-ground air-dried biomass (t/ha) of different trees grown in sodic soil
Pj=Prosopis juliflora, An= Acacia nilotica, Ce= Casuarina equisetifolia, Ta= Terminalia arjuna

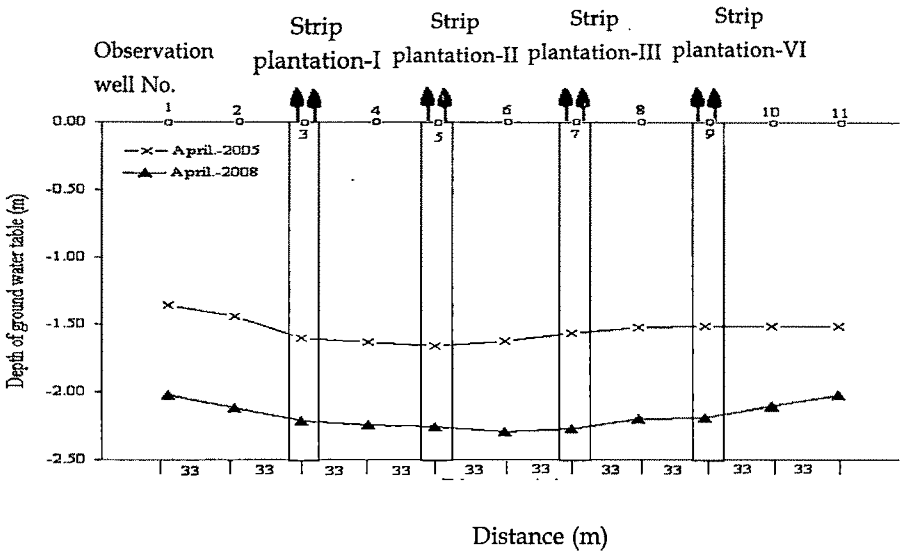

Fig. 2. Trend of ground water table under plantations and adjacent field

carbon (Ram Jeet *et al.*, 2011). After harvest trees could coppice further. Benefit--cost ratio of the first rotation of strip plantations (excluding crop yield) was 3.5 : 1 and it would be many folds for next 3 to 4 rotations due to negligible cost of coppiced Eucalyptus. Wheat yield in the interspaces of strip-plantations was 3.4 times that in adjacent waterlogged areas without plantation. It was mainly because of lowering of the water table and improvement in soil properties.

Efficient water management techniques

With the increase in demand of water from allied sectors, agriculture must improve water use efficiency generally. Adding climate change to this mix only intensifies the demands on water use in agriculture. With hotter temperatures and changing precipitation patterns, controlling water supplies and improving irrigation access and efficiency will become increasingly important. Climate changes will burden currently irrigated areas and may even outstrip current irrigation capacity due to general water shortages, but farmers with no or less access to irrigation are clearly most vulnerable to changed scenario. Therefore, there is urgent need of technologies and investments that improve water use efficiency, access to irrigation or to find ways to improve incomes with less secure and more variable water availability. Popularization of micro-irrigation is the need of hour to maximize the water productivity with each drop of water. Improving the inefficiencies in delivering system also require investment and farmers participation for integrated water management. To discourage injudicious and excess use of water for production, there is need for rational pricing of surface and groundwater which can arrest its excessive and injudicious use in overexploited regions like Punjab, Haryana and Tamil Nadu whereas development of infrastructure could create a situation of better utilization of groundwater in the region of less use of ground water like eastern India.

The cultivation methods and practices do influence the water productivity in the changed scenario of climate change. Since rice is the major crop in Indian subcontinent and is the major water consumer among all the crops. Studies conducted with different cultivation methods indicated that the system of rice intensification (SRI) method produced 22 higher grain yield with 24.5 water saving compared to transplanted rice (Geethalakshmi *et al.*, 2011). Water productivity was also maximum under SRI method of rice cultivation (0.58 kg/m"), followed by alternate wetting and drying method, and aerobic rice cultivation (Table 5). Beside water saving, SRI method of planting significantly reduced the methane emission (Yan *et al.*, 2009)

Table 5. Grain yield and water productivity in different rice cultivation systems

System of cultivation	Grain yield (kg/ha)	Water saving over conventional method (%)	Water productivity (kg/m^3)
Transplanting method (Conventional)	6032^b	-	0.36^c
Direct sowing rice	5175^c	6.2	0.33^d
Alternate Wetting and Drying	5111^c	25.7	0.41^b
System of Rice Intensification (SRI)	7359^a	24.5	0.58^a
Aerobic rice	3582^d	42.3	0.37^c

Means within the column followed by the same letter are not significantly different (LSD at P = 0.05)
Source: Geethalakshmi *et al.* (2011)

thus indicating that SRI method of cultivation will suit better under future warmer climate in terms of economizing water and increasing the productivity. Efforts should be initiated to develop the package of practices for SRI in different agro-ecological regions and popularization of this technology in the current scenario.

With dwindling water availability, 'deficit irrigation' can make a substantial difference in productivity in the areas having limited access to irrigation. In rain-fed areas, water conservation and water harvesting techniques should be given due consideration for higher productivity. Greater emphasis on water harvesting and improving the efficiency of regional as well as farm water use efficiency could help to face uncertain rainfall. Policies are needed that would encourage farmers to conserve water and use it judiciously. For example financial compensation/incentive/subsidy for increasing the efficiency of irrigation water use through drip and sprinkler methods could encourage farmers to improve soil health, manage with less water, and assist in overall sustainable development.

Since freshwater supplies are limited and has competing uses, and would become even more constrained in changed global climate, we have to start vigorous evaluation of using industrial and sewage wastewater in agriculture. Such effluents, once properly treated can also be a source of nutrients for crops. Since water serves multiple uses and users, effective inter-departmental co-ordination in the Government is needed to develop the location-specific framework of sustainable water management and optimum recycling of water.

Crop diversification

The crop diversification is useful in providing higher protection against risk associated with climate change in addition to assured net returns to the farmers. Risk reduction through crop diversification related to climatic and biotic vagaries particularly in fragile ecosystems and commodity fluctuations by expanding locally adapted or introducing novel varieties and related production systems will contribute to improved food security and income generation for resource-poor farmers and protect the environment (Behera *et al.*, 2007). Rice-wheat cropping system is the most important cropping system for food security as it contributes 26 of total cereal production and 60 of total calorie intake (Gupta *et al.*, 2003). The area under the system is static and the productivity and sustainability of the system are threatened because of the inefficiency of current production practices, shortage of resources such as water and labour and socioeconomic changes (Ladha *et al.*, 2003). There is sufficient scope to replace rice-wheat cropping system with other cropping systems without any decline in economic yield rather it improved substantially (Gangwar and Singh, 2011). The maize-potato-onion, summer groundnut-potato-bajra, maize-potato-summer

Table 6. Net return, irrigation water applied and electric consumption of different cropping systems under Trans Gangetic Plains

Cropping System	Total variable cost (₹/ha/year)	Net return (₹/ha/year)	Irrigation water use efficiency (kg grain/m")	Electric consumption (units/ha/ annum of 5 HP motor)
Maize-potato-onion	83383	125023	130	1205
Groundnut-potato-bajra (F)	62435	111839	103	955
Maize-potato-moong	64250	78588	105	973
Maize-wheat-rnoong	48255	72797	92	853
Rice-Wheat	39318	59742	212	1963

(Source: Gangwar and Singh, 2011)

moong and maize-wheat-summer moong gave 2.1, 1.8, 1.7 and 1.3 times more productivity respectively over rice-wheat system which clearly elucidated the superiority of these systems over prevailing rice-wheat system. The maize-potato-onion system gave the highest productivity (27.8 t/ha/annum). The summer groundnut-potato-bajra (fodder) system gave 23.3t/ha/annum productivity with 103 cm irrigation water leading to 109 cm saving of water. The quantity of water used in the maize-potato-onion, summer groundnut-potato-bajra (f), maize-potato-summer moong and maize-wheat-summer moong was 38.7, 51.4,50.5 and 55.6 per cent less than quantity of water used for rice-wheat system. The corresponding value in terms of saving of electricity consumption (per ha basis) was 758, 1008, 990 and 1110 electricity unit, respectively (Table 6). It is reported that replacement of 5 area under rice-wheat cropping system (2.6 million ha) by these alternative crop sequences will amount to the saving of about 135850 ha-m irrigation water with additional net returns of Rs. 4650 million to the farmers and saving of 162 million electrical unit amounting Rs. 378 million (Gangwar and Singh, 2011) thus contributing a lot in reducing GHGs.

Resource conservation technologies

In the projected scenario of climate change, conservation agriculture holds good as adapting strategy to build up organic matter in soils and create a healthy soil ecosystem by not tilling the soil before each planting. Resource conservation technologies (RCTs) such as zero-tillage and bed planting have been shown to be beneficial in terms of improving soil health, water use, crop productivity and farmers' income (Gupta and Seth, 2007). Zero-tillage is widely adopted by farmers in the Northwestern India, particularly in areas where rice is harvested late. It has been well documented that ZT can save 13-33 water use and 75 fuel consumption (Malik *et al.*, 2002) whereas bed planting has the potential to save water by 30-50 in wheat (Kukal *et al.*, 2005).

In addition, such resource conserving technologies restrict release of soil carbon thus mitigating increase of CO_2 in the atmosphere. By increasing the organic matter in soils, conservation agriculture improves the moisture capacity of the soil and thereby increases water use efficiency. The practice also reduces carbon emissions by reducing tilling, although it also requires more sophisticated pest and disease control because the system is not 're-booted' at each planting. An array of other production management practices and technologies could similarly improve farmers' mitigation and adaptation to climate change, including equipment and information that enables more precise application of inputs, especially fertilizer. The key challenge is to assure that such practices do not reduce yields so that the demand for additional land offsets the benefits from on-field sequestration. Therefore, there is need to frame policies and incentives that would encourage farmers to sequester carbon in the soil and thus improve soil health, and water use and energy more efficiently.

Changes in land-use and management

Input management and sowing time plays an important role in adaptation to a limited extend in view of small changes in climatic parameters. Simple adaptations, such as change in planting dates, crop varieties and farming system (such as mixed/inter cropping, crop-livestock) could help in reducing impacts of climate change to some extent and ease the pressure on natural resources. For example, the losses in wheat production can be reduced from 4-5 to 1-2 million tonnes, if a large percentage of farmers could change to timely planting. This may, however, not be easy to implement due to constraints associated with wheat planting in rice-wheat and cotton-wheat cropping systems. Cultivating alternate crops or cultivars more adapted to changed environment can further ease the pressure. For example, in case of wheat, early planting or the use of long-duration cultivars may offset most of the loss associated with increased temperatures. Available germplasm of various crops needs to be evaluated for heat and drought tolerance. Recent researches have shown that surface seeding or zero-tillage establishment of upland crops after rice gives similar yields planted under normal conventional tillage over a diverse set of soil conditions. This reduces cost of production, allows earlier planting and thus higher yields, results in less weed growth, reduces the use of natural resources, such as fuel and steel for tractor parts, and shows improvements in efficiency of water and fertilizers.

Use of frontier biotechnological tools for improved biotypes

Increasing agricultural productivity requires use of frontier technologies through investments in breeding programmes which could spark substantial yield gains in adapting to climate change. Therefore, future breeding efforts would need to address multiple stresses like heat and drought tolerant, salinity tolerance, pest resistance cultivars to encounter impact imposed by changing climate. This would require extensive breeding efforts, which will depend on the collection, conservation and sharing of appropriate crop genetic material among plant breeders and other researchers. The genetic resources, especially land races from the areas where past climates mimicked the projected future climates, could serve as the serving pool for building genes for tolerance. Further, there is a need for a better understanding of wild relatives, landraces, creating trait-based collection strategies, and establishing pre-breeding as a public good for providing a suitable response to challenges of global climate change. A combination of conventional, molecular marker directed mutational and transgenic breeding approaches will be required to evolve the desired cultivars and varieties.

Improved risk management through early warning system and crop insurance

The increasing probability of floods and droughts and other uncertainties in climate may seriously increase the vulnerability of resource-poor farmers to global climate change. In such cases, adaption to environmental change could be in the form of crop insurance, subsidies, pricing policies, and change in land use. Necessary provisions need to be included in the development plans to provide protection to the farmers, if their farm production is reduced due to natural calamities. Weather derivatives could greatly help in adapting to increase climatic risks. In view of these climatic changes and trade scenarios, it will be very useful to have an early warning system of environmental changes and their spatial and temporal magnitude. Continued investments in remote sensing and weather forecasting are as important as ever. Modern tools of information technology could greatly facilitate this. Improvements in sensing and communication technology and in modeling techniques have brought sophisticated short-term forecasts to many parts of the world. More must be done to improve longer-term seasonal forecasts and to develop more effective forecasts of slow onset events such as drought. Policies to support the diffusion of this information and to help interpret these forecasts in terms of their agronomic and economic implications are required to help farmers in a big way.

CONCLUSION

Climate change is likely to threaten the food security and livelihoods of millions of people in India. Models generally predict that rising temperatures, increased climate variability and extreme weather events could significantly impact food production in the coming decades. Consistent warming trends and more frequent and intense extreme weather events have been observed across India in recent decades. Recent climatic events like cold wave, heat wave, drought, and floods have demonstrated the significant potential of weather factors to influence the production of food crops. Therefore, there is a need for using modern science combined with indigenous wisdom of the farmers to enhance the resilience of Indian agriculture to climate change. Development of multiple stresses tolerant varieties, efficient cropping systems, resource conservation technologies, water harvesting and supplemental irrigation for drought proofing in rainfed areas can help in mitigating the adverse impact of climate change and variability. Alternate land use system like agro-forestry system and other biological carbon capture systems can also help in both adaptation and mitigation. Accurate and reliable forecasting of environmental changes will be of immense use and policies to support the dissemination of this information are required to help farmers in a big way. Researchers and policy framers should develop a comprehensive adaptation and mitigation strategies for coping the adverse impact of climate change.

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Impact of climate change on soil health*

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ABSTRACT

The increasing concentration of greenhouse gases (GHGs) is bringing about major changes to the global environment resulting in global warming, depletion of ozone concentration in the stratosphere, changes in atmospheric moisture and precipitation and enhanced atmospheric deposition. These changes impact several soil processes, which influence soil health. In this paper, the impact of climate change on soil health especially on soil organic C (SOC) and N dynamics in soil and strategies to improve SOC pool and soil health are discussed. A number of physical, chemical and biological characteristics have been proposed as indicators of soil quality. Soil organic matter (SOM) exerts a major influence on several soil quality indicators and is thus considered a key indicator of soil health. An optimal level of SOM is essential for maintaining soil health and alleviating rising atmospheric CO_2 concentration. Management practices or technologies that increase C input to the soil and reduce C emissions or both enhance soil organic C pool. Biological processes in soil such as decomposition of organic matter, C and N cycling, microbial and metabolic quotients are likely to be influenced greatly by climate change. Changes in climate are likely to influence dynamics of SOM, both directly through changes in temperature and water balance and indirectly through changes in primary productivity. Future trend in SOC content will depend on the relative temperature sensitivities of organic matter decomposition and primary production. During the last 150 years atmospheric N depositions have increased greatly and these are projected to increase further by ~2.5 times by the year 2100. The deposited N besides impacting a number of processes in soil significantly modifies the global C and N cycles. In view of changing climate, it is imperative to maintain soil health as a healthy soil can sustain its functions and provide ecosystem resilience.

There is an increasing recognition that the emission of carbon dioxide (CO_2), methane (CH_4), oxides of nitrogen (nitrous oxide, N_2O and nitric oxide, NO) and halocarbons (a group of gases containing fluorine, chlorine and bromine), which emanate from human activities are bringing about major changes to the global environment. The concentration of these greenhouse gases (GHGs) in the environment has increased significantly with time. The atmospheric concentration of CO_2 has increased globally by more than 100 ppm (39%) from about 275 ppm in the pre-industrial era (AD 1000-1750) to 383 ppm at present. Direct instrumental measurements show that during the period 1960 to 2005 the atmospheric CO_2 concentration increased at 1.4 ppm/yr. The atmospheric concentration of CH_4 has almost tripled since the pre-industrial times and the ice core records indicate that the abundance of CH_4 in atmosphere has varied from about 400 ppb during glacial periods to about 700 ppb during interglacials (Spahni *et al.*, 2005). In 2005, the global average abundance of CH4 was 1774 ± 1.8 ppb (Forster *et al.*, 2007). Methane contributes about 16% of the global warming resulting from the increasing concentrations of GHGs in the atmosphere. Methane has an atmospheric lifetime of about 12 years and plays an important role in atmospheric oxidation chemistry and affects stratospheric ozone and water vapour levels. In recent years, atmospheric growth rate of CH_4 seems to stagnate, or even decline. However, there is a large interannual variability, with growth rates ranging from a high of 14 ppb/year in 1998 to less than zero in 2001, 2004 and 2005. The reasons for the decrease in the atmospheric CH_4 growth rate and the implications for future changes in its atmospheric burden are not understood. Nitrous oxide contributes about 6% of the anthropogenic greenhouse effect. Its concentration in the atmosphere has been increasing by about 0.25% per year, from about 270 ppb in pre-industrial times to 319 ppb in 2005. In the 1990s the concentration of N_2O in the atmosphere has increased by 0.8 ppb/year. Nitrous oxide is fairly stable and has a global atmospheric lifetime of 120 years but because of its own feedback the lifetime decreases by about 0.5% for every 10% increase in N_2O and has thus adjusted lifetime of 114 years. The global warming potential (GWP) of N_2O is 296 times that of CO_2 over a 100-year time horizon (IPCC, 2001).

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The increased concentration of GHGs cause global warming, deplete the concentration of ozone in the stratosphere that acts as a shield against excessive exposure to ultra violet (UV) rays at the Earth's surface, and also contribute to acid deposition. During the period 1906-2005, global mean surface temperatures have risen by 0.74°C ± 0.18°C and is expected to increase by another 1.1-6.4°C by the end of this century (IPCC, 2007). However, the warming has neither been steady nor the same in different seasons or at different locations. The rate of warming during the last over 50 years is almost double (0.13°C ± 0.03°C per decade) than that during the last 100 years (0.07°C ± 0.02°C per decade). In addition to temperature, atmospheric moisture, precipitation and atmospheric circulation have also changed. Radiative forcing alters heating, and at the Earth's surface this directly affects evaporation as well as sensible heating. Increase in temperature influences evaporation, sensible heat and moisture-holding capacity of the atmosphere (at a rate of ~7% per °C). Together these effects alter the hydrological cycle, especially amount, frequency, intensity, duration, type and extremes of precipitation (Trenberth *et al.*, 2003). The changes in temperature, moisture, increased CO_2 concentration and enhanced atmospheric deposition impact several soil processes, which influence soil health. The objective of this paper is to: i) briefly describe criteria for soil health assessment, ii) discuss the impact of climate change on soil health especially on soil organic C (SOC) and N dynamics in soil, and iii) present management practices for improving SOC pool and soil health and elucidate the significance of soil C sequestration in off-setting anthropogenic emissions and mitigating climate change.

SOIL HEALTH ASSESSMENT

Soil health also termed soil quality refers to the functioning of soil within ecosystem boundaries to sustain biological productivity, maintain environmental quality and promote plant and animal health. It represents a composite of physical, chemical and biological attributes. Carter *et al.*, (1997) distinguished between inherent and dynamic soil quality. Inherent soil quality depends on the soil's mineral composition, soil texture and depth and usually does not show much change with time, except for degradation by erosion, deposition or desertification. However, static soil properties provide basis for how soil management practices may influence dynamic soil properties. The dynamic soil properties are subject to change with time, climatic conditions and management practices. The examples of dynamic soil quality parameters include SOM, microbial biomass and diversity, soil respiration, C and N mineralization rates. Dynamic soil properties indicate whether the management practices being adopted are sustainable or not.

Several physical, chemical and biological characteristics (Table 1) have been proposed as indicators of soil quality (Nieder and Benbi, 2008). Physical attributes most commonly used to define soil quality include soil texture, depth of soil and rooting, soil bulk density, aggregation, infiltration, water holding capacity, water retention characteristics, water content and soil temperature. Chemical parameters that can be used to assess soil quality include total SOM, active organic matter content, pH, electrical conductivity (EC), and available nutrient concentrations. Total SOM content defines a soil's carbon storage, potential fertility (nutrient

Table 1. List of commonly used soil quality indicators

Indicator	Soil property
Physical	Soil texture, aggregate distribution, aggregate stability, maximum rooting depth, bulk density, penetration resistance, porosity, hydraulic conductivity, infiltration, water holding capacity, mineralogy
Chemical	Organic C, labile C, organic C fractions of different oxidizability, total N, mineral N, pH, electrical conductivity, available nutrient status, cation exchange capacity, potentially toxic elements, organic chemical contaminants
Biological	Microbial biomass C and N, potentially mineralizable N, soil respiration, metabolic quotient, respiratory quotient, enzyme activities, phospholipid fatty acid, DNA

availability), and stability. Active organic matter content defines a soil's structural stability and the quantity of food available for microbes. Microbes can only grow and function at an optimum pH range; most microbes cannot function at low and at high pH. The EC of the soil can be an indicator of plant and microbial activity thresholds. Above or below different predetermined EC levels, specific plant and microbial communities will not function successfully.

Biological parameters that can be used to indicate soil health include microbial biomass C and N, potentially mineralizable N, specific microbial respiration rates, microorganism numbers, and the presence of mycorrhizae. The microbial C and N masses are important for determining microbial health as in general a C:N ratio of 8:1 is necessary for adequate soil function. The C:N ratio indicates whether the organic matter is having substantial amount of C and N to sustain microbes. Measurement of potentially mineralizable N in soil could be used to estimate indigenous soil N supply. Microbial activity indicators include the microbial respiration or the CO_2 evolution rates. No single parameter is sufficient to describe soil quality. Larson and Pierce (1994) proposed a quantitative formula for assessing soil quality and relating changes to soil management. Generally, a composite of parameters based on soil physical, chemical and biological properties and processes is used to develop soil quality index (SQI) (e.g. Karlen *et al.*, 1997; Andrew *et al.*, 2004). To quantify soils quality, a minimum data set comprised of a small number of selected soil physical chemical and biological indicators is needed. The choice of the data set is based on an understanding of the relationship between a SQI and soil function.

SOIL ORGANIC CARBON: A KEY INDICATOR OF SOIL QUALITY

Soil organic matter exerts a major influence on soil physical, chemical and biological properties (Table 2). The physical properties most commonly affected include soil bulk density, aggregate stability and moisture retention. In general, soil bulk density decreases as the SOM content increases. A significant correlation between SOM content and change in bulk density has been reported (Khaleel, *et al.*, 1981). Addition of organic amendments is known to decrease soil bulk density (Benbi *et al.*, 1998). Reduction in soil bulk density may be attributed to the dilution effect of adding less dense organic matter to the more dense mineral matter and increased aggregation. The increase in aggregate formation and aggregate stability is mainly due to the production of organic macromelecules by microorganisms that bind primary particles and microaggregates to form macroaggregates. The addition of organic amendments to soils has been found to be an effective method to increase total aggregation and the proportion of water-stable aggregates (Benbi *et al.*, 1998; Sodhi *et al.*, 2009). Soil organic matter can influence water retention directly and indirectly. The direct effect depends on the morphological structure of the organic materials and through its effect on reducing evaporation. The indirect effect arises from its

Table 2. Soil properties and processes influenced by soil organic matter (Source: Adapted from Baldock and Nelson, 2001)

Property	Function/Process
Aggregate stability	Aggregation of soil particles and formation of macro-aggregates from micro-aggregates
Water retention	Change in water holding capacity through increase in water absorption and modification of pore size distribution
Soil colour	Change in soil thermal properties
Exchange capacity	Adsorption of cations and anions from soil solution
Buffering capacity	Proton buffer in slightly acidic to alkaline soils
Source of nutrients	Availability of nutrients through mineralization
Energy source	Metabolic energy for biological processes
Microbial biomass activity	Stimulation or inhibition of microbial biomass and activity
Enzyme activity	Indication of the oxidative activities of the soil
Interactions with metals and organics	Retention/ mobilization of metals; alteration of biodegradability and persistence of organics
Ecosystem resilience	Soil organic matter pool and nutrient availability can enhance the ability of an ecosystem to recover after natural or anthropogenic disturbances

impact on soil aggregation and pore size distribution, and thus on water holding capacity of soil. The SOM imparts dark color to the soil and thus can enhance soil warming resulting in promotion of temperature-dependent biological processes such as mineralization of C, N and S.

The chemical properties that are mainly influenced by SOM include nutrient availability, exchange capacity of the soils, reaction with metals and contaminants and its capacity to act as proton buffer. Soil organic matter provides pH buffering in most surface soils and acts over a wide range of soil pH. The ability of SOM to adsorb both cations and anions from the soil solution is important for maintenance of soil quality. It contributes 25-90% of the cation exchange capacity of surface layers of mineral soils (Stevenson, 1994). The soil biological properties/processes influenced by SOM include mineralization, microbial biomass and enzyme activities. Apparently, SOM influence several soil properties and processes that determine soil health and adaptation to climate change.

PRACTICES TO INCREASE SOIL CARBON POOL

From the discussion in the preceding section it is clear that an optimal level of SOM is essential for several key soil properties and processes, which are strong determinants of soil health. It is, therefore essential that agro-ecosystems are managed to increase SOM, which will help in alleviating rising atmospheric CO_2 concentration, improving soil structure, and decreasing soil erosion and land degradation. Management practices or technologies that increase C input to the soil and reduce C loss or both enhance SOC pool. Increased C input in agro-ecosystems can be achieved by addition of organic amendments (e.g. animal manure, compost, sludge, green manure etc.), crop residue recycling, integrated nutrient management, intensification of agriculture through improved nutrient and water management practices, selection of high biomass producing crops, and adoption of agroforestry systems. Soil carbon loss could be decreased by adopting conservation agriculture and minimizing soil disturbance, checking erosion through reduced tillage intensity, and using low quality organic inputs. Addition of organic manures/composts results in improved soil aggregation (Benbi *et al.*, 1998) and greater C sequestration especially in macroaggregates (Benbi and Senapati, 2010; Sodhi *et al.*, 2009). Intensive agriculture with improved nutrient and water management results in enhanced SOC pool due to higher crop productivity and greater return of crop residues, root biomass and root exudates to soil. Results of a 25-year study showed that intensive agriculture with rice-wheat system resulted in improved SOC content and favourable pH (Benbi and Brar, 2009). Results of several studies have shown that C sequestration is higher under submerged rice soils as compared to aerobic soils due to incomplete decomposition of organic materials, and decreased humification of organic matter under flooded conditions (Sahrawat, 2004). Though several management practices lead to C sequestration, the appropriate practices to increase soil C reserves are site-specific. This will require evaluation and adaptation with reference to soil type and land use system. Globally, potential for C sequestration in soils over 50 year period has been estimated to be 24-43 Gt C, which corresponds with about 9-12% of the anthropogenic CO_2-C produced annually. In India, more than 100 million hectares are classified as degraded and greatly depleted in SOM. It has been suggested that only by reclamation of salt-affected wasteland in India, upto 2 Gt C could be sequestered. Thus, C sequestration in soil has great impact not only on the quality of the soil for its sustainable use but also the quality of the environment.

EFFECT OF CLIMATE CHANGE ON SOIL HEALTH

While several reports are available relating soil health to agricultural management, the studies describing the effect of climate change on soil health are rare. This is mainly because the changes in soil properties and the climate take place over a long-term. A change in soil quality can only be perceived when all the effects are combined over a period of time. Generally, biological processes in soil such as decomposition and storage of organic matter, C and N cycling, microbial and metabolic quotients are likely to be influenced greatly by climate change and have thus high relevance to assess climate change impacts (Allen *et al.*, 2011; Table 3). Physical indicators of soil quality such as porosity and available water capacity have high relevance and are occasionally used to assess climate change

Table 3. Soil quality indicators and soil processes with high relevance to assess climate change impacts (Source: adapted from Allen *et al.*, 2011)

Indicator	Soil process affected
Soil organic matter fractions	Residue decomposition, organic matter storage and quality
Mineralizable C and N	Metabolic activity of soil organisms, mineralization-immobilization turnover
Total C and N	C and N mass and balance
Soil respiration, soil microbial biomass	Microbial activity
Microbial quotients	Substrate use efficiency
Microbial diversity	Nutrient cycling and availability
Porosity	Air capacity, plant available water capacity
Available water	Field capacity, permanent wilting pointing, water flow

Table 4. Soil quality indicators and soil processes with medium relevance to assess climate change impacts (Source: adapted from Allen *et al.*, 2011)

Indicator	Soil process affected
Soil structure	Aggregate stability, soil organic matter turnover
pH	Biological and chemical activity thresholds
EC	Plant and microbial activity thresholds
Available N, P and K	Plant available nutrient and potential for loss

impacts. Chemical indicators of soil quality such as pH, EC and availability of nutrients have medium relevance and are frequently used to assess climate change impacts (Table 4).

Simulation models are increasingly used to generate scenarios and predict the possible effects of climate change on soil health. Soil organic matter models such as Century and Roth-C are being used for regional and global analysis of soil C dynamics (Allen *et al.*, 2011; Table 3) .

Organic matter dynamics

Globally, soils contain 1500-2000 Gt organic C down to 1 m depth. It has turn-over times ranging from months to millennia, with much of it around several years and decades. Depending on the input-output balance, SOM can be both a source and sink of atmospheric CO_2. A soil source results when net decomposition exceeds C inputs to the soil, either as a result of human activities or because of increased decomposition rates due to global warming. Simulations with Roth C model (Coleman and Jenkinson, 1996) has shown that the increase in global temperature will result in enhanced soil respiration rates and hence decreased soil carbon stocks, estimated at 54 Gt C by the year 2100 (Niklaus and Falloon, 2006). Similarly, Smith *et al.* (2005) estimated that soil carbon stocks in European croplands and grasslands will decrease due to enhanced decomposition but increased net primary productivity is likely to slow the loss.

Changes in climate are likely to influence the rates of accumulation and decomposition of SOM, both directly through changes in temperature and water balance and indirectly through changes in primary productivity and rhizodepositions (Fig. 1). Atmospheric CO_2 concentration influences SOM storage through its effect on primary production. Generally, it is expected that increase in temperature will enhance the rate of SOM decomposition, which decreases SOC content. Increased temperature together with elevated CO_2 concentration will lead to increase in primary productivity, which provides input to SOC. The change in soil C storage represents the net effect of organic matter decomposition and primary production. Studies in the past have shown that soil organic C and N pools are positively correlated with precipitation and negatively correlated with temperature (Post *et al.*, 1982; Post *et al.*, 1985). There are contradictory reports on the effect of temperature increase on SOC. Simulation studies of Kirschbaum (1993) showed that temperature increase could result in loss of SOC due to increased decomposition. On the contrary, Gifford (1992) predicted no loss of SOC due to temperature increase. Since SOC pools is influenced by rate of organic matter decomposition and primary productivity, the future trend in SOC pool will depend on the relative temperature sensitivities of the two processes. The temperature sensitivity of organic matter decomposition decreases with increasing temperature and at low temperature it is much greater than the temperature sensitivity of net primary productivity (Kirschbaum, 1995). Using a simple productivity model coupled to the SOM model, CENTURY (Parton *et al.*, 1987), Kirschbaum (1995) showed that SOC content may decrease greatly at low temperature and the loss of C per degree warming will decrease with increasing temperature. The C loss per degree warming may be as high as 10% in regions with

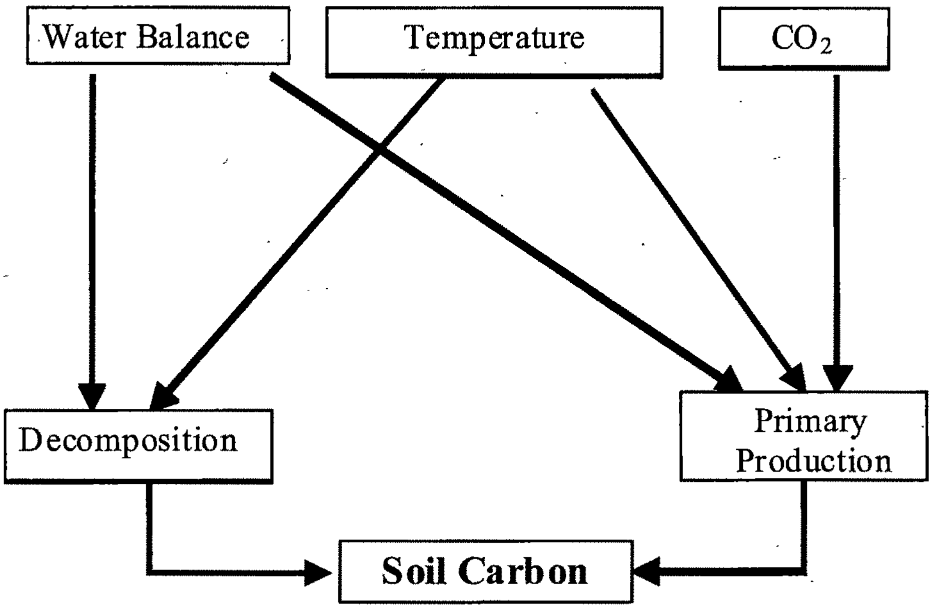

Fig. 1. Climatic factors affecting soil carbon pool

mean annual temperature of 5°C and only about 3% for a soil at 30°C. These results suggest that climate change could result in depletion of SOC content and the soils may provide a positive feedback in the global C cycle. However, to predict the fate of SOC stocks in relation to global warming it is essential to understand the temperature response of the processes that control substrate availability, depolymerization, microbial efficiency and enzyme production (Conant *et al.*, 2011).

Nitrogen dynamics

The amount and distribution of nitrogen in different forms in the soil depends upon a number of interlinked input processes, transformations and loss processes (Benbi and Richter, 2003). Mineralization and immobilization of nitrogen, nitrification, fixation and release of NH_4^+ comprise the nitrogen transformation processes. The N input pathways include fertilizer application, biological nitrogen fixation by legumes and atmospheric wet and dry deposition. Global estimates of total atmospheric N deposition show great increase during the last 150 years and these are projected to increase further by ~2.5 times by the year 2100 (Lamarque *et al.*, 2005). Compared to total annual NOy deposition of 12.8 Tg N in 1860 the deposition has increased to 45.8 Tg N in early 1990s (Galloway *et al.*, 2004). Compared to estimated input of 1-3 kg N ha^{-1} yr^{-1} in the early 1900s (Galloway, 1995; Asman *et al.*, 1998), the atmospheric N deposition rates of 20-60 kg N/ ha/yr in non-forest ecosystems, and up to 100 kg N/ ha/yr in forest stands in Europe or the USA have been reported (Bobbink *et al.*, 2002). The high deposition rates could be attributed to biomass burning, soil emissions of NO_x and NH_3 as well as lightning production of NO_x.

The deposited N besides impacting a number of processes in soil significantly modifies the global C and N cycles. Nitrogen deposited to agricultural or croplands could serve as a source of nutrient, but it could also adversely affect several processes in the soil. Increased N deposition may lead to reduction in biodiversity, soil acidification, increased N_2O emissions from denitrification and nitrification in soils, altered balance of nitrification and mineralization/ immobilization, increased nitrate leaching and eutrophication. Because a number of factors determine the severity of an effect of N deposition, there is high variations in response of different ecosystems to atmospheric N deposition.

High N deposition in forests may enhance the accumulation of C and N in SOM through increased biomass production (Aber *et al.*, 1998). In N-limited temperate ecosystems, N deposition can enhance C storage, which could impact atmospheric CO_2 concentration (Townsend *et al.*, 1996).

Soil erosion and salinization

Global warming, greater high and low extremes of rainfall due to climate change are expected to subject soils to significant risk of climate induced physical and chemical degradation. In most parts of Asia, forest is shrinking, agriculture is gradually expanding to marginal lands and land degradation is accelerating through nutrient leaching and soil erosion. About 20% of the agricultural land in Asia has been degraded over the last several decades (Foley *et al.*, 1998). Unsustainable irrigation and management practices in conjunction with climate change, have lead to deterioration of soil health due to increased salinization, nutrient depletion and erosion. An estimated 950 million ha of salt-affected lands occur in arid and semi-arid regions, constituting about 33% of the potentially arable land area of the world.

From the foregoing it is clear that climate change could impact SOM and a number of processes that are strong determinant of soil health. To mitigate climate change effects, it is imperative that soil health is maintained so that it can sustain physical, chemical and biological functions and provide ecosystem resilience.

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Integrated nutrient management on performance of wheat (*Triticum aestivum* L.)

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ABSTRACT

The experiment was conducted at Agricultural Research Station, Durgapura, Jaipur during 2006-07, 2007-08. The results showed that the application of 120 kg N + 40 kg P_2O_5/ha and poultry manure @ 6t/ha by broadcasting recorded the maximum number of effective tillers, grains per ear, ear length, 1,000 grain weight, grain, straw and biological yields of wheat. The extent of increase in grain and straw yield was 49.51 and 46.64 per cent with the application of 120 kg N + 40 kg P_2O_5/ha over lowest level. The extent of increase in grain and straw yield was 49.5 and 46.6 per cent with the application of 120 kg N + 40 kg P_2O_5/ha and 55.5 and 42.3 per cent with the application of poultry manure @ 6t/ha by broad casting. A pot experiment of organic amendment on survival of bio-agent in soil was also planned; the results indicated that the efficacy of bio-agent increased the soil due to application of organic amendment. The population of *Triticum harzianum* was significantly higher in soils amended with farm yard manure, vermin-compost or mustard cake.

Key words: Integrated nutrient management, poultry manure, bio-agent.

Wheat is one of the most important staple food crop of India and occupies a notable position among the food grain crops not only in area and production but also in its versatility in adaptation to a wide range of agro-climatic conditions. The area, production and productivity of wheat in India were 29.9 million ha, 93.9 mt and 31.4 q ha during 2011-12, respectively (Anonymous, 2012 a). In Rajasthan, wheat is an important *rabi* crop and is grown through out the state. The area, production and productivity of crop in Rajasthan were 2.93 million ha, 1.04 million tones and 34.84 q/ha, respectively during 2011-12 (Anonymous, 2011b). Enhanced use of chemical fertilizers for increasing production has been widely recognized but their indiscriminate use may have adverse effect on soil health, ecology and other natural resources, the high cost of fertilizer also restricts their large scale use. Therefore, to reduce dependence on chemical fertilizers and maintenance of high production levels are vital issues in modern agriculture which is only possible through integrated nutrient management (INM). Use of organic manures in INM helps in mitigating the multiple nutrient deficiencies. Addition of organic manures provides favourable environment for plant growth in addition to causing improvement in physical, chemical and biological properties of soil. Integrated nutrient management involves the integrated use of mineral fertilizers together with organic manure in suitable combination compliments and each other to optimize input use and maximize production and sustain the same without impairing the crop quality or soil health. It enables gainful utilization of organic wastes. The present study was designed to find out the effect of integrated nutrient management on performance of wheat crop.

MATERIALS AND METHODS

The field experiment was conducted with wheat variety Raj-3077. The soil of the experimental field was loamy sand, alkaline in reaction, having pH (7.8), EC (0.16 ds/m), low in available nitrogen (151.5 kg/ha) and in phosphorus (21.5 kg/ha) medium, in potassium (194.6 kg/ha). The experiment was laid out in split-plot design with four replications, the fertilizer levels were taken in main plots and poultry manure in sub plot, with four levels of fertilizer (30 kg N + 10 kg P_2O_5/ha, 60 kg N + 20 kg P_2O_5/ha, 90 kg N + 30 kg P_2O_5/ha and 120 kg N + 40 kg P_2O_5/ha) and six levels of poultry manure (control, 2t/ha broadcasting, 2t/ha by drilling, 4t/ha broadcasting, 4t/ha by drilling, 6t/ha broadcasting, 6t/ha by drilling). After harvest of the crop the soil samples were collected using core sampler from each plot. The crop was irrigated timely at different stages as per its requirement for proper plant growth. To assess the biological, grain and straw yield, net area of 4 m x 2.7 m was harvested separately from each plot. For survival of bio-agent study, the 10 g soil was added in 90 ml sterilized water in erlenmeyer flask and shacked gently for 4-5 minutes. Serial dilutions were made from stock soil suspension upto 10^7 add 0.2 ml soil suspension of suitable dilution (depending on stage of soil sampling) was done to the surface of *Trichoderma harzianum* selective medium (Elad and Chet, 1983) and spread uniformly with the help of glass spreader. The inoculated petridishes were incubated at 25°C for 5 to 6 days and the *Trichoderma harzianum* colonies developed were counted (Papavizas, 1985). The earthen pots were filled with natural field soil and amended with farm yard manure at 20 g/kg soil, vermi-compost at 10 g/kg soil and mustard cake at 2 g/kg soil. Talc based formulations of four respective bio-agents were applied to amended soil at 2 g/kg soil. In case of control, the test bio-agents were added separately to unamended soil. Each treatment was replicated thrice.

RESULTS AND DISCUSSION

Effect of fertilizer levels

Results revealed that application of 120 kg N + 40 kg P_2O_5 ha recorded significantly higher number of effective tillers, grains/ear, ear length and test weight (Table 1). The grain and straw yield increased to the extent of 49.5 and 46.6 per cent with the application of 120 kg N + 40 kg P_2O_5/ha. Increased supply of nitrogen to plant promotes flowering and fruiting, higher manufacture of food and its subsequent partitioning in sink. Thus adequate supply of nitrogen and phosphorus nutrients to plant in balance proportion improved the yield attributing characters and yield. Same results were also reported by Dubey *et al.* (1997) and Nehra *et al.* (2000).

Effect of poultry manure

Application of 6t/ha poultry manure through drilling significantly increased the effective tillers, ear length, grains/ear and test weight (Table 1). The extent of increase in grain and straw yield was 49.5 and 46.6 per cent with the application of 120 kg N + 40 kg P_2O_5/ha and 55.5 and 42.3 per cent with the application poultry manure @ 6t/ha by broad casting. The beneficial effect of poultry manure on yield attributes was probably due to enhanced nutrient supplied during the entire growing season. These inputs maintained in the highest values of crop productivity in terms of grains, straw and biological yields under this treatment (Table 2). The similar results was also reported by Agarwal, S.K. (2004). The significant increase in grain and straw yields under the influence of poultry manure was largely a function of improved growth and consequent increase in different yield attributes as mentioned above. The possible reason could be ascribed to the favorable effect on soil properties due to formation of more humus colloidal complex coupled with higher nutrient content of poultry manure (Singh and Shrivastava, 1970).

Effect of organic amendment with bioagent in soil

Bareja and Lodha (2002) studied the survival of *Trichoderma harzianum* in different composts prepared from on farm wastes, farm yard manure and soil. The population of microbial antagonists in presence of organic amendment was influenced in soil reported by (Chattopadhaya *et al.*, 1999 ; Bora *et al.*, 2000). The recovery of this bio-agent was higher at 30 days of applications as compared to 0 days *i.e.*, immediately after the soil application. The population of the bio-agent started reducing after 60 days of soil application *i.e.*, mid January. The population was gradually reduced during the months of February, March, April and May *i.e.*, up to 180 days of soil application in all the amended soils and control. The survival of the bio-agent was relatively better in mustard cake amended soil as compared to farm yard manure and vermicompost amended soils. Whereas,

Table 1. Effect of fertilizer and poultry manure on yield attributes of wheat

Treatments	Effective tillers/m row			Ear length (cm)			Grains/ear			1000 grain weight (g)		
	2006-07	2007-08	Pooled	2006-07	2007-08	Pooled	2006-07	2007-08	Pooled	2006-07	2007-08	Pooled
Fertilizer												
30 kg N + 10 kg P_2O_5/ha	53.6	54.3	53.9	7.8	7.9	7.8	40.3	40.5	40.4	34.3	34.3	34.3
60 kg N + 20 kg P_2O_5/ha	61.7	62.8	62.3	8.3	8.3	8.3	42.1	42.6	42.4	35.3	35.4	35.4
90 kg N + 30 kg P_2O_5 /ha	66.9	68.1	67.5	8.5	8.5	8.5	43.9	44.6	44.2	36.2	36.4	36.3
120 kg N + 40 kg P_2O_5/ha	70.5	72.1	71.3	8.6	8.6	8.6	45.3	46.1	45.7	37.1	37.5	37.3
S Em ±	0.81	0.92	0.61	0.18	0.17	0.12	0.67	0.63	0.46	0.46	0.54	0.36
C.D. (P = 0.05)	2.58	2.92	1.81	0.56	0.54	0.35	2.13	2.02	1.37	1.47	1.73	1.05
Poultry manure												
Control	52.2	53.2	52.7	7.7	7.7	7.7	39.8	40.0	39.9	33.8	34.0	33.9
2 t/ha broadcasting	60.0	61.0	60.5	8.3	8.3	8.3	42.1	42.4	42.2	35.3	35.5	35.4
2 t/ha drilling	60.6	61.8	61.2	8.3	8.4	8.3	42.3	42.5	42.4	35.4	35.6	35.5
4 t/ha broadcasting	64.4	65.5	65.0	8.4	8.4	8.4	43.4	43.7	43.6	36.1	36.2	36.2
4 t/ha drilling	65.0	66.0	65.5	8.4	8.4	8.4	43.6	43.9	43.8	36.2	36.3	36.2
6 t/ha broadcasting	69.7	71.0	70.4	8.5	8.5	8.5	44.5	45.9	45.2	36.7	36.8	36.8
6 t/ha drilling	70.1	7.9	71.0	8.5	8.5	8.5	44.7	46.0	45.4	36.8	36.9	36.8
S Em ±	0.89	0.95	0.65	0.17	0.16	0.12	0.67	0.64	0.46	0.59	0.58	0.41
C.D. (P = 0.05)	2.51	2.67	1.82	0.47	0.45	0.33	1.88	1.81	1.29	1.65	1.64	1.15

Table 2. Effect of fertilizer levels and poultry manure on yields (t/ha) and harvest index (%) of wheat

Treatments	Grain yield			Straw yield			Biological yield			Harvest index		
	2006- 07	*2007-08*	*Pooled*	*2006-07*	*2007-08*	*Pooled*	*2006-07*	*2007-08*	*Pooled*	*2006-07*	*2007-08*	*Pooled*
Fertilizer												
30 kg N + 10 kg P_2O_5/ha	3.2	3.4	3.3	4.5	4.6	4.5	7.7	8.0	7.9	41.6	42.6	42.1
60 kg N + 20 kg P_2O_5/ha	3.8	4.1	4.0	5.4	5.4	5.4	9.2	9.5	9.4	41.8	42.7	42.2
90 kg N + 30 kg P_2O_5 /ha	4.3	4.6	4.5	6.0	6.1	6.1	10.4	10.8	10.6	41.8	42.8	42.3
120 kg N + 40 kg P_2O_5/ha	4.8	5.1	4.9	6.6	6.7	6.7	11.4	11.8	11.6	41.9	42.9	42.4
S Em ±	0.73	0.82	0.55	1.04	1.43	0.89	1.61	2.09	1.32	0.51	0.57	0.39
C.D. (P = 0.05)	2.33	2.61	1.63	3.31	4.58	2.62	5.13	6.66	3.91	1.64	1.83	1.14
Poultry manure												
Control	3.0	3.2	3.1	4.4	4.5	4.5	7.5	7.8	7.6	40.5	41.1	40.8
2 t/ha broadcasting	3.6	3.8	3.7	5.2	5.3	5.2	8.5	9.2	9.0	41.1	42.3	41.7
2 t/ha drilling	3.7	3.9	3.8	5.2	5.3	5.3	9.0	9.3	9.1	41.4	42.4	41.9
4 t/ha broadcasting	4.2	4.4	4.3	5.9	6.0	5.9	10.2	10.5	10.3	42.1	43.0	42.6
4 t/ha drilling	4.3	4.5	4.4	5.9	6.0	5.9	10.3	10.6	10.4	42.2	43.1	42.6
6 t/ha broadcasting	4.7	4.9	4.8	6.4	6.4	6.4	11.1	11.4	11.3	42.4	43.5	42.9
6 t/ha drilling	4.8	5.0	4.9	6.4	6.5	6.4	11.2	11.5	11.4	42.7	43.8	43.3
S Em ±	0.71	0.75	0.52	1.33	1.35	0.95	1.83	1.90	1.32	0.61	0.63	0.44
C.D. (P = 0.05)	1.99	2.11	1.44	3.73	3.80	2.64	5.13	5.33	3.67	1.71	1.77	1.22

Table 3. Effect of organic amendments on population of *Trichoderma harzianum* in soil (CFU g^{-1} soil)

Soil amendments	Dose	Days after application						
	(g kg^{-1} soil)	0 Day ($\times 10^6$)	30 Day ($\times 10^6$)	60 Day ($\times 10^5$)	90 Day ($\times 10^5$)	120 Day ($\times 10^4$)	150 Day ($\times 10^4$)	180 Day ($\times 10^3$)
Farm yard manure	20	18.2	24.2	28.7	25.0	12.2	10.0	22.5
Vermi-compost	10	19.5	23.7	25.5	22.5	10.5	8.2	20.7
Mustard cake	2	20.7	24.7	33.7	29.5	13.2	11.5	24.0
Control	-	19.0	17.2	15.0	11.5	5.7	3.2	4.7
S Em ±		0.62	0.25	0.62	0.69	0.26	0.31	0.42
C.D. (P=0.05)		NS	0.77	1.91	2.13	0.80	0.94	1.30

Table 4. Effect of fertilizer and poultry manure application on net returns (Rs/ha) and B:C ratio

Treatments	Net returns (₹r/ha)			B:C ratio		
	2006-07	2007-08	Pooled	2006-07	2007-08	Pooled
Fertilizer						
30 kg N + 10 kg P_2O_5/ha	21,479	23,043	22,261	1.5	1.6	1.6
60 kg N + 20 kg P_2O_5/ha	28,217	30,099	29,158	2.0	2.1	2.1
90 kg N + 30 kg P_2O_5/ha	33,397	35,521	34,459	2.3	2.5	2.4
120 kg N + 40 kg P_2O_5/ha	37,772	40,115	38,944	2.6	2.8	2.7
S.Em ±	735	879	573	0.06	0.70	0.04
C.D. (P = 0.05)	2346	2805	1698	0.18	0.21	0.13
Poultry manure						
Control	22,322	23,774	23,048	2.0	2.1	2.0
2 t/ha broadcasting	26,822	28,918	27,870	2.0	2.2	2.1
2 t/ha drilling	27,438	29,394	28,416	2.1	2.2	2.1
4 t/ha broadcasting	31,764	33,752	32,758	2.2	2.3	2.3
4 t/ha drilling	32,366	34,296	33,331	2.2	2.3	2.3
6 t/ha broadcasting	35,206	37,352	36,279	2.2	2.3	2.3
6 t/ha drilling	35,596	37,878	36,737	2.2	2.3	2.3
S Em ±	750	792	545	0.05	0.06	0.04
C.D. (P = 0.05)	2107	2227	1520	0.15	0.16	0.11

survival of *Trichoderma harzianum* was relatively less as compared to amended soils all through out the study *i.e.,* up to 180 days of soil revealed application (Table 3).

Economics: Data (Table 4) revels that increasing levels of N and P increased the net returns significantly over lower levels during both the years and the maximum B:C ratio (2.7) was recorded with the application of 120 kg N +40 kg P_2O_5/ha followed by 90 kg N + 30 kg P_2O_5/ha (2.45).

Application of poultry manure @ 6 t/ha by drilling significantly increased the net returns and B:C ratio of wheat as compared to control. The application of poultry manure @ 6 t/ha by drilling as well as broadcast recorded B:C ratio 2.3 followed by application of 4 t/ha poultry manure by drilling (2.31).

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Estimation of heterosis in diverse cytoplasmic male sterile sources of Pearl millet [*Pennisetum glaucum* (L.) R. Br.]

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ABSTRACT

Among the available sources of cytoplasmic male sterility only the A_1 source has so far been exploited for developing commercial hybrids in pearl millet (*Pennisetum glaucum* (L.) R. Br.). In the present study, heterosis over better parent and commercial check were estimated in lines belonging to A_1, A_4 and A_5 cytoplasms for fifteen yield attributing and physiological traits. Heterosis was observed in A_1 source for plant height, days to maturity, spike girth, 1000 seed weight, harvest index, chlorophyll a, carotenoid content and membrane stability index. For days to 50% flowering, number of productive tillers per plant, spike length, grain yield per plant, biomass and chlorophyll b, heterosis was observed in lines belonging to A_4 cytoplasmic source. Significant heterotic values were observed for panicle harvest index in A_5 cytoplasm.

Key words: Heterosis, heterobeltiosis, physiological and yield contributing traits, pearl millet.

Pearl millet [*Pennisetum glaucum* (L.) R. Br.] is the most drought tolerant warm season cereal crop grown as a staple food grain and source of feed and fodder on about 26 million hectares in Asia, Africa and Latin America. It is grown primarily under very hot and dry conditions in soils of low fertility and water-holding capacity where other crops fail completely. In India, pearl millet is the most widely cultivated cereal after rice and wheat. It is grown on more than 9.3 m. ha with production of 9.5 m. tonnes and productivity of 1,044 kg/ha (http://www.agricoop.nic.in). The major pearl millet growing states are Rajasthan, Maharashtra, Gujarat, Uttar Pradesh and Haryana, which account for nearly 90 percent of the acreage under pearl millet. The grain production has increased from 3.5 to 9.5 m tonnes with 47.9% increase in production due to adoption of high-yielding cultivars and suitable agro-production technologies.

Pearl millet provides the main source of nutritious staple food grain, high-energy feed grain (for milch and draft animals, as well as for poultry, fish, and other mono-gastric livestock), and green and dry fodder for ruminant livestock. It is also grown as a forage crop in south-eastern USA, Australia and Brazil. With substantial increase in pearl millet production in India especially during last three decades, additional pearl millet grain is being diverted to cattle feed in northern India, poultry feed in southern India and also in beverage industries. Though there are no base line surveys available, it is estimated that 40-50% of pearl millet grain is being diverted to be used in feed and other industries.

Pennisetum glaucum (L.) R. Br is a cross pollinating, diploid ($2n=2x=14$) annual with haploid genome size of 2,450 Mbp. Exploitation of hybrid vigour is one of the most efficient means of elevating the productivity potential, particularly in cross pollinated crops. It is well established that the pearl millet hybrids perform better than open pollinated cultivars. High levels of heterosis for grain yield have been indicated in pearl millet (Rawat & Tyagi, 1989 and Ugale *et al.*, 1989). The performance of a larger number of hybrids based on CMS lines under a wide range of agro-ecological conditions in India was demonstrated by (Rachie *et al.*, 1967). These hybrids were found to be superior to the parental lines as well as open-pollinated varieties, and some of the best hybrids out yielded the controls by margins ranging from 75-200%.

Cytoplasmic male sterility (CMS) is considered an efficient tool in pearl millet breeding. A_1, A_2, A_3 (Burton and Athwal, 1967), A_4 (Hanna, 1989), A_5 (Rai, 1995), violaceum [Marchais and Pernes, 1985) and Ex- Borne (Aken'Ova, 1985) are seven different CMS sources in pearl millet. Of these the A_1, A_2, A_3, Av, A_4 and A_5 are distinctly different CMS systems. All most all the single cross F_1 hybrids cultivated in India and USA are based on the A_1 CMS system and have contributed significantly in increasing productivity of pearl millet in India (Dave, 1987 and Talukdar *et al.*, 1997). Although other sources of CMS such as A_2, A_3, and A_4 were discovered, the A_1 source continues to be the most exploited source in commercial hybrid breeding (Yadav, 1994). Based on the history of hybrid development in India, it is evident that some popular hybrids, most importantly, HB 3, HB 4, BJ 104 and MBH 110, all were based on A_1 CMS system (Dave, 1987 and Govila, 1998) and had to be withdrawn from farmers' fields because of susceptibility to the downy mildew. A critical appraisal revealed that failure of these hybrids was mainly due to lack of diversity in the parental lines, as all the hybrids were first based on Tift 23 A_1 and then on 5141A_1 (Govila, 2001). Thus, a clear need is felt for diversification of the cytoplasmic bases of hybrids to reduce the potential hazards of vulnerability and also to provide opportunities for greater exploitation of hybrid vigour (Delorme *et al.*, 1997).

Suitability of the many different sources of cytoplasm for development of successful pearl millet hybrids is also challenging as it requires stable male sterile female parents, maintainers for sterility and restorers for fertility restoration along with yield superiority. Hence, the present study was undertaken with the objective of estimating the heterosis in diverse cytoplasmic male sterile sources (A_1, A_4 and A_5) of pearl millet.

MATERIALS AND METHODS

The material for the present study comprises of 14 female parents from diverse cytoplasmic male sterility sources (A_1, A_4 and A_5) and 5 elite restorers (A_1) obtained from Pearl millet breeding programme of Indian Agricultural Research Institute New Delhi (IARI) and International Crops Research Institute for Semi Arid Tropics, Patancheru. The fourteen female parents included the male sterile lines- MS 5141A, MS 843A, ICMA 88004, ICMA 89111, ICMA 91444, ICMA 92111, ICMA 93333, ICMA 95111 belonging to A_1 cytoplasm, ICMA 98333, ICMA 99222, ICMA 99555, ICMA 00777, ICMA 04888 belonging to A_4 cytoplasm and ICMA 07999 (A_5 cytoplasm) and the five restorers of A_1 cytoplasm as testers D 23, PPMI 69, PPMI 493, PPMI 741 and PPMI 761 along with one commercial hybrid check (Pusa 415). The parents were mated in *Kharif*, 2009. In the *kharif*, 2010, the experiment was conducted in the experimental farm of Division of Genetics, IARI in three replications. For the estimation of heterosis only 26 hybrids were selected based on the fertility restoration of the F_1 hybrids which recorded more than 60% fertility restoration under selfed conditions (Alidad Amiribehzadi and Tara Satyavathi, 2012). Geographically, the experimental site is situated at an altitude of about 228m above mean sea level with 28° 40' North latitude and 77° 13' E longitude. This region has a semi-arid subtropical climate with alluvial soil, which is slightly alkaline with clay loam texture and low organic matter.

The observations on physiological, yield and yield components were recorded on five randomly selected plants for each genotype in each replication. The fifteen traits included were days to 50% flowering (DTF), days to maturity (DTM), plant height(PH), number of productive tillers per plant (PT), spike length (SL), spike girth (SG), 1000-grain weight (SW), grain yield per plant (g) (GYP), biomass (kg/ha)(BM), harvest index(HI), panicle harvest index(PHI) and four physiological traits namely chlorophyll a(Chl a), chlorophyll b(Chl b), carotenoid content (CC) and membrane stability index(MSI). The DMSO method was used for estimation of photosynthetic pigments and carotenoids (Arnon, 1949). The membrane stability index (MSI) was determined as per Sairam *et al.* (2009). The extent of heterosis for yield, yield components and physiological traits were calculated using the standard procedures like - heterosis estimates in (%) of F_1 better parent (BP) and commercial check (PUSA 415) were computed following Turner (1953) and Hayes *et al.* (1955).

RESULTS AND DISCUSSION

The analysis of the variance for 19 parents (14 diverse cytoplasmic male sterile lines and 5 testers of A_1) and 26 F_1 crosses for the 15 characters related to grain yield and physiological aspects showed significant differences (Table 1). The analysis of variance revealed presence of high amount of variability for the characters namely - plant height, days to 50% flowering, days to maturity, number of productive tillers, spike length, spike girth, 1000-grain weight, grain yield per plant, biomass (kg/ ha), panicle harvest index, chlorophyll a, chlorophyll b and membrane stability index. This is in the lines of expectation as the parental material comprised different cytoplasms like A_1, A_4 and A_5 and hence in the hybrids as well. Similar results were reported by Rai *et al.*, 2006 and Tara Satyavathi *et al.*, 2009.

Heterosis

Heterosis breeding has been recognized as the most suitable breeding methodology for augmenting yield in pearl millet. Selection of suitable parents and assessment of degree of heterosis in the resulting crosses forms an important step (Manga *et al.*, 2004). The expression of heterosis in the cultivar crosses clearly indicates the agronomic potential of the hybrids (Ouendeba *et al.*, 1993).

The number of heterotic crosses, range of heterosis and the best three crosses over better parent (BP) i.e. heterobeltiosis and commercial check (CC) i.e. commercial heterosis for the fifteen yield contributing and physiological traits are presented in Table 2. Heterosis may be desirable both in the positive and negative direction. Among the 26 hybrids in the present study, the cross ICMA 88004 x PPMI 741 belonging to A_1 cytoplasm exhibited significant heterosis over the best parent (14.02%) and the cross ICMA 89111 x D 23 belonging to A_1 cytoplasm showed commercial heterosis of 36.36%for plant height.

For days to 50% flowering, the cross ICMA 04888 x PPMI 741 belonging to A_4 cytoplasm showed -4.73% of heterobeltiosis over the better parent and -7.20% commercial heterosis over the commercial check Pusa 415. In case of days to maturity, the cross ICMA 91444 x D 23 belonging to A_1 cytoplasm showed -4.13% heterosis over the better parent and the cross 5141 A x D23 belonging to A_1 cytoplasm showed commercial heterosis of -6.02%. The negative heterosis denotes earliness and is a desirable mechanism of drought avoidance and disease escape under the short moisture availability period in the arid regions.

Table 1. ANOVA for the pearl millet genotypes involved in the present study

Source of variance	Replication	Genotypes	Error
d.f.	2	44	88
Plant height (cm)	182.50	2431.70**	24.88
Days to 50% flowering	7.22	11.56**	0.58
Days to maturity	4.72	22.41**	0.56
No. of productive tillers	0.05	1.16**	0.17
Spike length (cm)	0.82	40.37**	0.52
Spike girth (cm)	0.02	0.56**	0.01
1000 grain weight (g)	0.40	5.20**	0.07
Grain yield per plant(g)	16.63	2211.29**	17.76
Biomass (g)	6612.00	162796.85**	722.21
Harvest index	0.00	0.00	0.00
Panicle harvest index	0.00	0.02*	0.00
Chlorophyll a	0.61	1.52**	0.03
Chlorophyll b	0.08	0.06*	0.00
Carotenoid content	0.10	0.03	0.01
Membrane stability index	440.06	460.40**	30.54

*; ** Significant at 5% level; significant at 1% level

Table. 2. Heterosis over better parent (Heterobeltiosis) and commercial check (Commercial heterosis) for the best three crosses belonging to A_1, A_4 and A_5 cytoplasmic sources of male sterility in Pearl millet for various yield attributing and physiological traits of importance

Character	Heterosis	Range of heterosis		Crosses	Cytoplasm
		Minimum	Maximum		
Plant height	Best parent	-15.52	14.02	ICMA 88004 x PPMI 741(14.02)	A_1
				ICMA 89111 x D 23(13.45)	A_1
				ICMA 98333 x PPMI 741(13.08)	A_4
	Commercial check	-2.00	36.36	ICMA 89111 x D 23(36.36)	A_1
				ICMA 88004 x PPMI 741(32.90)	A_1
				843 A x PPMI 761(29.35)	A_1
Days to 50% flowering	Best parent	8.55	-4.73	ICMA 04888 x PPMI 741(-4.73)	A_4
				ICMA 99222 x PPMI 741(-3.61)	A_4
				ICMA 00777 x D 23(-3.57)	A_4
	Commercial check	-7.20	-2.10	ICMA 04888 x PPMI 741(-7.20)	A_4
				ICMA 88004 x PPMI 493(-5.99)	A_1
				ICMA 93333 x PPMI 741(-5.23)	A_1
Days to maturity	Best parent	3.72	-4.13	ICMA 91444 x D 23(-4.13)	A_1
				5141 A x D 23(-3.31)	A_1
				ICMA 88004 x PPMI 493(-2.99)	A_1
	Commercial check	-6.02	0.00	5141 A x D 23(-6.02)	A_1
				ICMA 88004 x PPMI 493(-5.81)	A_1
				ICMA 91444 x D 23(-5.50)	A_1
Number of productive tillers	Best parent	-33.33	28.57	ICMA 04888 x PPMI 761(28.57)	A_4
				ICMA 00777 x D 23(28.57)	A_4
				ICMA 88004 x D 23(28.57)	A_1
	Commercial check	-33.33	38.46	ICMA 88004 x D 23(38.46)	A_1
				ICMA 04888 x PPMI 761(28.57)	A_4
				ICMA 00777 x D 23(28.57)	A_4
Spike length (cm)	Best parent	-27.15	13.43	ICMA 98333 x PPMI 741(13.43)	A_4
				ICMA 91444 x D 23(13.16)	A_1
				ICMA 00777 x D 23(9.87)	A_4
	Commercial check	-15.71	42.73	843 A x D 23(42.73)	A_1
				843 A x PPMI 761(31.10)	A_1
				ICMA 91444 x D 23(29.32)	A_1
Spike girth(cm)	Best parent	-42.80	23.66	843 A x PPMI 761(23.66)	A_1
				ICMA 04888 x PPMI 761(20.80)	A_4
				5141A x PPMI 741(11.83)	A_1
	Commercial check	-30.61	32.85	ICMA 04888 x PPMI 741(32.85)	A_4
				843 A x PPMI 761(31.80)	A_1
				ICMA 04888 x PPMI 761(27.18)	A_4
Seed weight (g)	Best parent	-24.17	50.00	ICMA 93333 x D 23(50.00)	A_1
				ICMA 93333 x PPMI 761(36.05)()	A_1
				ICMA 89111 x PPMI 69(35.53)	A_1

	Commercial check	-12.22	55.06	ICMA 93333 x D 23(55.06)	A_1
				ICMA 89111 x PPMI 69(40.95)	A_1
				ICMA 93333 x PPMI 761(36.84)	A_1
Grain yield per plant (g)	Best parent	-27.27	246.88	ICMA 04888 x PPMI 761(246.88)	A_4
				ICMA 07999 x PPMI 493(167.96)	A_5
				ICMA 93333 x PPMI 761(164.58)	A_1
	Commercial check	5.35	316.25	ICMA 04888 x PPMI 761(316.25)	A_4
				ICMA 07999 x PPMI 493(228.57)	A_5
				ICMA 93333 x PPMI 761(204.19)	A_1
Biomass(g)	Best parent	-34.21	122.36	ICMA 04888 x PPMI 761(122.36)	A_4
				ICMA 88004 x PPMI 493(88.44)	A_1
				ICMA 88004 x PPMI 741(70.98)	A_1
	Commercial check	-12.28	151.78	ICMA 04888 x PPMI 761(151.78)	A_4
				ICMA 88004 x PPMI 493(103.80)	A_1
				ICMA 88004 x PPMI 741(82.32)	A_1
Harvest index	Best parent	-49.32	143.03	5141 A x PPMI 741(143.03)	A_1
				ICMA 99222 x D 23(132.31)	A_4
				ICMA 93333 x PPMI 741(101.94)	A_1
	Commercial check	-30.57	160.20	5141 A x PPMI 741(160.20)	A_1
				ICMA 99222 x D 23(153.16)	A_4
				5141 A x D 23(116.99)	A_1
Panicle harvest index	Best parent	-10.68	71.57	ICMA 07999 x PPMI 493(71.57)	A_5
				ICMA 93333 x PPMI 493(36.26)	A_1
				ICMA 99555 x PPMI 741(26.98)	A_4
	Commercial check	-5.28	75.44	ICMA 07999 x PPMI 493(75.44)	A_5
				5141 A x PPMI 741(74.78)	A_1
				5141 A x D 23(60.84)	A_1
Chlorophyll a	Best parent	-65.24	42.01	ICMA 93333 x PPMI 741 (42.01)	A_1
				ICMA 93333 x PPMI 493(40.65)	A_1
				ICMA 07999 x PPMI 493(15.25)	A_5
	Commercial check	-59.89	76.53	ICMA 93333 x PPMI 493(76.53)	A_1
				ICMA 07999 x PPMI 493(56.05)	A_5
				ICMA 93333 x PPMI 741(50.14)	A_1
Chlorophyll b	Best parent	-65.41	192.94	ICMA 99555 x PPMI 741(192.94)	A_4
				ICMA99222 x D 23(79.28)	A_4
				ICMA93333 x PPMI741(53.85)	A_1
	Commercial check	-55.77	211.25	ICMA99555 x PPMI 741(211.25)	A_4
				ICMA 99222 x D 23(89.52)	A_4
				ICMA 93333 x PPMI 741(78.77)	A_1
Carotenoid content	Best parent	-55.56	114.46	ICMA 89111 x D 23(114.46)	A_1
				ICMA 89111 x PPMI 69 (59.04)	A_1
				ICMA 04888 x PPMI 761(56.72)	A_4
	Commercial check	-52.00	163.70	ICMA 89111 x D 23(163.70)	A_1
				ICMA 89111 x PPMI 69(78.38)	A_1

				ICMA 04888 x PPMI 741(70.73)	A_4
Membrane stability index	Best parent	-41.65	44.31	ICMA 91444 x D 23(44.31)	A_1
				843 A x PPMI 761(35.01)	A_1
				ICMA 93333 x D 23(28.19)	A_1
	Commercial check	-39.66	48.41	ICMA 91444 x D 23(48.41)	A_1
				ICMA 88004 x PPMI 493 (44.56)	A_1
				ICMA 88004 x PPMI 741(39.04)	A_1

For number of productive tillers, heterobeltiosis was observed in the cross ICMA 04888 x PPMI 761 (28.57%) belonging to A_4 cytoplasm and commercial heterosis in ICMA 88004 x D 23 (38.46%) belonging to A_1 cytoplasm over the commercial check Pusa 415.

For spike length, the cross ICMA 98333 x PPMI 741 belonging to A_4 cytoplasm showed heterobeltiosis (13.43%) and the cross 843 A X D23 belonging to A_1 cytoplasm showed significant commercial heterosis of 42.73%. In case of spike girth, significant heterobeltiosis was observed for the cross 843 A X PPMI 741 (23.66%) belonging to A_1 cytoplasm and standard heterosis in the cross ICMA 04888 X PPMI 741 (32.85%) belonging to A_4 cytoplasm over the commercial check hybrid Pusa 415. Earhead weight and grain yield per plant exhibited highest heterotic values, whereas, least heterosis was observed for days to flowering (Dangaria *et al*, 2009).

High heterobeltiosis was observed for ICMA 93333 X D 23 (50.00%) belonging to A_1 cytoplasm, high standard heterosis of 55.06% was observed for the same cross for 1000 seed weight. High heterobeltiosis of 246.88% and standard heterosis of 316.25% was observed in the cross ICMA 04888 x PPMI 761 belonging to A_4 cytoplasm. The same cross ICMA04888 x PPMI 761 belonging to A_4 cytoplasm showed high and significant heterobeltiosis (122.36%) and standard heterosis (151.78%) for biomass. High heterobeltiosis values (143.03%) and high standard heterosis (160.20%) for harvest index were observed in the cross 5141 A x PPMI 741 belonging to A_1 cytoplasm. The heterobeltiosis values (71.57%) and commercial heterosis values (75.44%) for panicle harvest index were high in the cross ICMA 07999 X PPMI 493 belonging to A_5 cytoplasm.

For the photosynthetic pigments like chlorophyll a, the cross ICMA 93333 X PPMI 741 belonging to A_1 cytoplasm showed high and significant heterobeltiosis of 42.01%, whereas the cross ICMA 93333 X PPMI 493 belonging to A_1 cytoplasm showed commercial heterosis of 76.53%. For the photosynthetic pigment chlorophyll b, the cross ICMA 99555 x PPMI 741 belonging to A_4 cytoplasm showed significant positive heterosis of 192.94% heterobeltiosis and 211.25% of commercial heterosis. For the carotenoid pigment, the cross ICMA 89111 x D 23 belonging to A_1 cytoplasm showed heterobeltiosis of 114.46% and 163.70% of commercial heterosis over the better parent and the commercial check respectively. For membrane stability index the cross belonging to A_1 cytoplasm ICMA 91444 x D 23 showed 44.31% heterobeltiosis and 48.41% commercial heterosis. Chandra Shekhara *et al.* (2006) studied effect of cytoplasm and cytoplasm nuclear interactions on combining ability and heterosis for agronomic traits using alternate CMS sources.

CONCLUSION

The overall results of heterobeltiosis and commercial heterosis indicated that the parents involved in the crossing have contributed to the superior performance of the hybrid progenies. In the present study the observed heterosis for different traits was contributed by the diverse nature of the female parents belonging to different cytoplasmic sources i.e. A_1, A_4 and A_5. The present study offers great scope for exploitation of the diverse cytoplasmic sources for development of high yielding superior performing hybrids of pearl millet on commercial scale.

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Effect of different proportions of vermicompost and fertilizers on growth and yield of scented rice and soil properties

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ABSTRACT

A field experiment was conducted during rainy (*kharif*) season of 2007 and 2008 at Jabalpur, M.P. to study the combined effect of different proportions of vermicompost and fertilizers on growth and yield of scented rice. Application of 100% NPK through fertilizers significantly influenced the growth and yield attributes of rice compared with application of vermicompost alone and different combination of vermicompost and inorganic fertilizers. The grain and straw yields were recorded highest with recommended dose of fertilizers closely followed by the substitution of proportions of NPK proportions (20% and 40% N) with vermicompost. The NPK uptake was maximum with the recommended dose of fertilizers. The highest gross return with application of 100% N through vermicompost. The net returns and B:C ratio was maximum with the application of 100% NPK through fertilizers being at par with application of 20% N through vermicompost + 80% NPK through fertilizers. The highest cost of cultivation with organic nutrient management resulted into less net returns than inorganic nutrient management. The lowest cost of cultivation with inorganic nutrient management alone with good gross monetary returns (GMR) contributed to the maximum net monetary returns (NMR) value. The treatment considered with the substitution of proportion of NPK with proportions of vermicompost fetches less NMR value than the application of 100% NPK through fertilizers.

Key words : Vermicompost, fertilizers, rice, Pusa basmati.

Ancient agriculture in India was almost organic farming later on it has been shifted gradually towards modern chemical intensive agriculture with the advancement of science, technology and civilization. Although agricultural production has increased in modern agriculture mainly due to development of high yielding crop varieties, adoption of improved crop production technologies, use of synthetic agro-chemicals (fertilizers, insecticides, fungicides, herbicides and growth regulators etc. Under such circumstances, a change from chemically intensive agriculture to a more sustainable form of organic agriculture is desirable to overcome the constraints of modern agriculture. The addition of organic matter in the soil can play an important role in maintaining the soil health by supplying almost all essential plant-nutrients and providing good physical and biological conditions for growth and development of crop plants. Organic manures are very well known source to improve soil property and fertility for sustaining the soil by excluding or minimizing the dependence on chemical fertilizers. So use of organic manure such as vermicompost is another alternative for plant nutrition (Barik, 2008). The vermicompost may be a good source of almost all essential nutrients (primary, secondary and micronutrients) for plant growth and it is an eco-friendly natural fertilizer prepared from bio-degradable organic wastes, free from toxic chemical inputs. This compost is odourless, clean and being rich in nutrient elements as well as containing several micronutrients essential for plant growth. But the concentration of nutrients is less as compared to chemical fertilizers. So the nutritional need of rice crop cannot be fulfill by application of only vermicompost. However scented rice cv. Pusa Basmati-1 is high yielding variety and it require huge quantity of nutrients for obtaining optimum yield. Under such circumstances, integrated use of vermicompost and fertilizers in proper proportions appears to be the right practice of plant-nutrition (Barik, 2004). In rice growing areas, organically produced scented rice has better scope to obtain better market price as well as good export opportunity. But the productivity of organically grown rice is quite less than that of rice grown with the use of improved production technologies including agro-chemicals *viz.*, fertilizers, herbicides and pesticides. Cultivation of scented rice under organic farming situation appears to be one of the remunerative cropping system in rice growing areas because of its high market value in the domestic markets and in export potential. Under such circumstances, the combined use of vermicompost and fertilizers in proper proportions may be another option which may be cheap, socially acceptable and environmentally sound, nutrient management for increasing productivity of crops in sustainable manner. Therefore, it is essential to assess the ability of vermicompost to replace certain proportions of fertilizers to be applied in scented rice without declining the yields.

MATERIALS AND METHODS

The field experiment was conducted during *kharif* season of 2007 and 2008 at the Krishi Nagar Research Farm of Jabalpur, Madhya Pradesh. The soil of the experimental field was sandy clay loam in texture, neutral (pH 7.35) in reaction, normal in EC (0.48 dS/m) with medium OC (0.68%) content and analyzing low in available N (215 kg/ha) and P (9.20 kg/ha), S (9.3 kg/ha) and Zn (1.5 kg/ha) and medium in available K (318 kg/ha) contents. Seven treatments viz., T_1- absolute control (no application of any manure and fertilizers), T_2- 100% N through vermicompost, T_3- 100% NPK through fertilizers, T_4- 20% N through vermicompost + 80% NPK, T_5- 40% N through vermicompost + 60%NPK, T_6- 60% N through vermicompost + 40% NPK, T_7- 80% N through vermicompost + 20% NPK were tested in randomized block design with 4 replications. The recommended dose of N 120 kg /ha as urea was applied in 3 equal splits at transplanting, tillering and panicle-initiation stages. In vermicompost treatments, well prepared vermicompost was incorporated before transplanting as per the treatments. Application of P_2O_5 and K_2O were uniform @ 60 kg and 40 kg/ha as single super phosphate and murate of potash respectively and all were applied basal. Manures and fertilizers were applied as per treatments. Rice cv. Pusa Basmati-1 was grown by transplanting method and rice seedlings were raised in nursery bed for this purpose. Twenty five days old seedlings of rice were transplanted with 20 cm x 20 cm planting geometry in 7.0 m x 6.0 m sized plots. Data on various growth parameters and yield attributing characters were recorded. Economic viability of the various treatments was also determined on per hectare area basis.

RESULTS AND DISCUSSION

Yield attributes

In rice, plant height, number of effective tillers/m^2, panicle length, grains per panicle and 1000- grain weight significantly higher with the application of 100% NPK through fertilizers and recomonded at par with the substitution of 20% and 40% NPK through vermicompost (Table 1). The plant height and dry matter production/m2 was significantly superior with the recommended dose of fertilizers. Vermicompost contain nutrients in organic form which mineralized into available form after a particular time. The conversion of nutrients from organic form to inorganic form unavailable to fulfill the timely needs of crop. This may be the reason for the poor growth of the plant-nutrition. The reduction of proportion of NPK through vermicompost equivalent to N correspondingly reduced the food accumulation in plants in terms of DMP/m^2 and finally contributed to reduce the number of tillers/m. These results were collaborated with the findings of Murali and Singh *et al.* (2007).

Yields

The grain yield was significantly superior with the application of recommended dose of fertilizers closely followed by the application of 20% N through vermicompost and 80% NPK through fertilizers and 40% N through and 60 % NPK through fertilizers. The organic nutrient

Table 1. Growth and yield attributes of rice as influenced by different treatments

Treatment	Plant height (cm)		Dry matter production (g/m^2)		Effective tillers /m^2		Panicle length (cm)		Grains /panicle		Test weight (g)	
	2007	2008	2007	2008	2007	2008	2007	2008	2007	2008	2007	2008
Control	51	65	1014	997	239	239	14	21	61	73	24	24
100% N through VC	61	68	1463	1245	252	258	15	22	73	82	24	24
100% NPK	64	80	1722	1685	281	283	16	23	75	86	25	25
20% N through VC + 80% NPK	64	79	1677	1625	273	276	16	23	75	84	25	25
40% N through VC + 60% NPK	64	79	1589	1530	263	269	16	23	74	84	25	24
60% N through VC + 40% NPK	63	77	1543	1415	260	266	16	23	74	83	25	24
80% N through VC + 20% NPK	62	75	1530	1355	254	263	15	22	74	83	24	24
SEm±	1	1	51	21	3	4	0	0	1	1	0	1
C.D. (P=0.05)	1	1	60	63	11	14	1	1	3	4	NS	NS

Table 2. Effect of different treatments on yield and economics of rice

Treatment	Grain yields (t/ha)		Straw yields (t/ha)		Harvest index (%)		GMR (₹/ha)	Net returns (₹/ha)	B:C ratio
	2007	2008	2007	2008	2007	2008			
Control	2.1	2.6	4.2	5.2	0.33	33.59	30131	15762	2.07
100% N through VC	3.3	3.5	6.9	6.9	32.33	33.9	51462	23538	1.75
100% NPK	4.0	4.2	8.0	8.5	33.27	33.3	49545	32212	2.63
20% N through VC	3.8	4.0	7.6	8.0	32.92	33.33	47346	27690	2.48
40% N through VC + 60% NPK	3.6	3.8	7.1	7.5	33.51	33.68	45637	23874	2.13
60% N through VC + 40% NPK	3.4	3.6	6.9	7.3	32.79	33.3	43991	19364	1.85
80% N through VC + 20% NPK	3.5	3.6	6.6	7.2	33.43	33.31	42175	17175	1.69
SEm±	1.23	1.37	3.41	3.86	0.30	0.28	-	-	-
C.D. (P=0.05)	4.22	4.07	12.24	11.46	NS	NS	-	-	-

Table 3. Nutrient uptake as influenced by different treatments in rice

Treatment	Total N uptake (kg/ha)		Total P uptake (kg/ha)		Total K uptake (kg/ha)		Available nutrient (kg/ha)					
	2007	2008	2007	2008	2007	2008	OC (%)	N	P	K	S	Zn
Control	111.9	85.3	30.0	21.2	57.3	97.5	0.66	209	8.7	367	9.0	1.2
100% N through VC	163.7	95.5	48.3	24.0	85.1	118.5	0.69	221	9.3	372	9.3	1.6
100% NPK	198.5	115.0	54.3	28.3	100.6	138.7	0.67	219	9.2	370	9.2	1.4
20% N through VC + 80% NPK	185.5	110.1	52.8	27.2	98.9	133.3	0.68	216	9.1	369	9.1	1.5
40% N through VC + 60% NPK	180.6	105.3	51.0	26.1	97.5	127.4	0.68	215	8.9	370	9.1	1.5
60% N through VC + 40% NPK	173.9	102.2	49.4	25.5	89.9	123.4	0.68	216	8.9	369	8.9	1.5
80% N through VC + 20% NPK	165.6	100.2	48.7	24.9	86.5	122.5	0.68	216	9.0	369	9.0	1.5
SEm±	15.3	3.4	0.3	0.9	0.3	4.1	0.67	212	9.0	366	9.0	1.5
CD.. (P=0.05)	45.5	10.2	0.9	2.6	0.8	12.3	0.66	209	8.7	367	9.0	1.2

management gave higher grain yield. The nutrient availability to the crop might be lesser under combined application of vermicompost and inorganic fertilizers resulting significantly inferior growth parameters, ultimately lesser grain yields. Application of 100% N through vermicompost resulted in production of significantly lesser grain yield than other treatments. These results are conformity of findings at Singh *et al.* 2003. The straw yield was also maximum with the100% RDF being on par with 20% N through vermicompost and 80% NPK through fertilizers and 40% N through and 60% NPK through fertilizers. The growth parameters *viz.*, plant height and number of effective tillers/ m^2 were markedly superior with inorganic nutrient management as a result of optimum supply of nutrients through fertilizers than combined application of vermicompost and inorganic fertilizers in different proportions and organic nutrient management. (Guo *et al.*, 2001). The influence of treatments on harvest index was not significant in both the years.

NPK uptake

The data on total NPK uptake in rice for 2 years are presented in (Table 3). The uptake of major elements NPK by the rice was maximum with the application of 100% NPK through fertilizers on both the years. The total N uptake was maximum with application of 100% NPK through fertilizers which was at par application of 20% N through vermicompost and 80% NPK through fertilizers and 40% N through and 60% NPK through fertilizers. The application of 100% NPK through fertilizers also recoded significantly highest total P and K uptake. Because of increased NPK nutrients at all critical stages owing to higher grain and straw yields. The uptake of nutrients correspondingly reduced, when quantity of NPK fertilizers proportionally reduced by the substitution of vermicompost equivalent to the rest proportion of N. The optimum requirement of nutrient at all critical stages of rice crop reduced with the application of 100% N through vermicompost which resulted into lesser uptake of nutrients by the rice. Similar results were also reported by Kathuria *et al.*, 2004.

Effect on soil fertility status

It is evident from the data table 4 that none of the chemical properties viz., organic content % (OC), available N, P, K, S and Zn did not much deviated from their initial status after the completion of experiment under different treatments. However, The all the available organic content (OC), available N, P, K, S and Zn was minimum under control plots, but it was enhanced under different nutrient management. The maximum available nutrients was observed under T_2 followed by T_3, T_4, T_6, T_7 and T_5.

Economics

Among seven treatments the highest gross returns (Rs. 51462) were recorded with 100% N through vermicompost led to significantly higher GMR than other treatments being at par with the 100% RDF on pooled data analysis of 2 years. (Table 2). The net returns and B:C ratio was maximum with the 100% RDF being at par with substitution of proportion of 20% NPK through vermicompost. The higher cost of cultivation with vermicompost resulted into lesser NMR than other treatments. The treatments associated with varying proportions of NPK through fertilizers and VC fetched the lesser NMRs than to those recorded with the application of 100% N through VC.

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Studies on fibre quality parameters of *inovulo* cultured interspecific triple cross of cotton

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ABSTRACT

Currently, spinning machinery used by the textile processing industry sets the standards for fibre quality and these are mostly based on the physical properties of fibre, especially strength. Therefore, an important breeding objective has been to introduce fibre strength genes from other *Gossypium* species or strains while maintaining the cotton fibre yield. Amongst wild *Gossypium* L. species, the African *Gossypium anomalum* produces cotton with good fibre strength and fineness. In this investigation, efforts were made to introgress superior fibre quality parameters from wild *G. anomalum* and *G. barbadense* into *G.arboreum* cotton and obtained hybrid between colchicide (*G. arboreum* x *G. anomalum*) x *G. barbandense.* In the present study F_3 and F_4 generation of *inovulo* cultured interspecific triple cross were evaluated to determine desirable fibre quality parameters for high spinning potential of the textile mills. On the basis of fibre analysis, seven F_3 segregants viz, 10aab/3, 9T/7, 9T/1, 30A/3, 4T/5, 73/9, 73/6 showed highest performance for the entire fibre quality attribute. Similarly 56/6-2, 4T/5-13, 9T/3-20, 13W/9-2, 45/3-18 and 9aab/8-5 F_4 plants had desirable fibre properties. Identification of these plants will enable to undergo the selection pressure for such type of plants in succeeding generation to enhance the fibre quality parameters.

Keywords: Interspecific triple cross, *G. anomalum, G. arboreum, G. barbadense.*

Cotton fibre is an important raw material for the textile industry. With the economic liberalization and globalization sweeping the world, there is a scope for our country to play a leading role in cotton production and export of textile yarn and raw cotton. As a result of the recent advances in the spinning technology, greater fibre quality, especially strength is required, which can survive the rigors of ginning, cleaning, carding, combing and drafting (Deusen, 1992). But the present day cultivars are lacking with higher fibre strength, essential to meet the requirements of spinning industry. Therefore, genetic improvement of fibre quality traits is the need of the hour for meeting the challenge of the textile industry. The modernization of textile industry and use of open end rotor spinning technologies has put a demand for cotton varieties and hybrids with high fibre strength (≥ 25 g/tex) with micronaire ranging from 4.0 to 4.5. One way to achieve this is through introgression of genes from wild sources for simproving the cultivated varieties through hybridization, backcrossing and polyploidy breeding.

Traditional methods of cotton breeding often fail due to incompatibility barriers like embryo or endosperm abortion (Pundir, 1972). Even in cases where hybridization is effective the frequency of hybrid formation is very low and eventually there is hybrid breakdown (Gerstel and Phillips, 1958). Therefore the desirable traits like fibre length, strength, fineness and resistance to disease and insect which though present in various species cannot be transferred into cultivated types.

Thus considering the current prospects of cotton crop, efforts were made to introgress superior fibre quality parameters from wild

G. anomalum (2n=2x=26 B_1B_1) and *G. barbadense* (2n=4x=52, $A_bA_bD_bD_b$) into *G. arboreum* cotton and obtain inter-specific triple cross hybrid between colchicide (*G. arboreum* x *G. anomalum*) x *G. barbadense* by utilizing the techniques of in-vitro production in cotton. The F_1 and F_2 generations of this triple cross were studied earlier, while F_3 and F_4 segregating generations of this interspecific cross are evaluated during present investigation with objective to study fibre quality parameters.

MATERIALS AND METHODS

The present research work was conducted at the Cotton Improvement Project, Mahatma Phule Krishi Vidyapeeth, Rahuri, District. Ahmednagar. during the period 2005-2009. The material consisted of parent *G. arboreum* (P_1), *G. anomalum* (P_2) and *G. barbadense* (P_3) and F_1 generation of *G. arboreum* x *G. anomalum* (C_1 doubled F_1) and F_1 triple hybrid colchicide (*G. arboreum* x *G. anomalum*) x *G. barbadense* and segregating generation *viz.*, F_3 and F_4 of the above cross.

Salient features of parental materials used during present study are as under:

Sr. No	Parents	Salient features
1.	G. arboreum var. MPKV GMS	Resistant to drought, tolerant to boll worms, aphids, black arm, reddening of leaves
2.	G. anomalum	Extremely fine fibre with good strength, resistant to jassids, leaf roller, red mites and tolerant to boll worm
3.	G. barbadense var. RHcb-001	Extra-long, fine and strong fibre, high spinning potential but susceptible to biotic and abiotic stress.

Fibre properties

Based on availability of sufficient lint for testing, selected plants were subjected for detailed investigation for fibre properties in F_3 and F_4 generations. Following characters were analyzed under HVI (High Volume Instrument) at Central Institute for Research on Cotton Technology (CIRCOT), Adenwala Road, Matunga, Mumbai.

Per cent span length (mm)

2.5 per cent span length (mm) is defined as the distance spanned by a specified percentage of the fibres in the specimen being tested. The fibre length at 2.5 per cent span was estimated and expressed in millimeters.

Fibre strength (g/tex)

It is the force required to break the fibre of unit linear density. The fibre strength was determined by and expressed in g/tex.

The fibre strength (g/tex)

$$= \frac{\text{Breaking strength (kg) x 15.0}}{\text{Weight of bundle (mg)}}$$

Micronaire (µg/inch)

It is the average weight per unit length of fibre. It is used in determining the fibre fineness. Linear density of fibre is expressed in micrograms per inch.

Uniformity ratio (%)

The ratios of 50 per cent span length to 2.5 per cent span length. It indicates the uniformity of the fibre length. The fibre uniformity ratio was estimated by using HVI expressed in percentage.

$$\text{Uniformity ratio} = \frac{\text{50 per cent SL}}{\text{2.5 per cent SL}}$$

RESULTS AND DISCUSSION

Based on the availability of lint, one hundred eighty nine plants from F_3 generation and sixty one plants from F_4 generation of a cross (*G. arboreum* x *G. anomalum*) x *G. barbadense* were subjected for detailed fibre property analysis at CIRCOT, Mumbai and data was obtained.

2.5% span length (mm)

In F_3 generation, the range of variation for this character among the plants selected was between 20.0 to 36.90 mm. while in F_4 segregating generation, 2.5 % span length ranged between 23.60 and 34.60. The progeny plant no 73/14 recorded highest 36.9 mm span length than the rest of the plants in F_3 generation. In F_4, 9aab/8-5 progeny plant no had highest 34.60 mm span length.

Uniformity ratio (%)

Uniformity ratio percentage was higher in F_4 generation than in F_3 generation. The highest uniformity ratio percentage (53%) was recorded in the F_3 plant progeny no 4T/6, 10aab/6 and 67/4. While highest uniformity ratio percentage (54%) was recorded in F_4 plant progeny No 71/2-8. The average uniformity ratio in F_3 and F_4 was 47.94 and 48.59 respectively.

Micronaire (g/inch)

The micronaire (g/inch) varied between range of 2.40 to 6.20 (g/inch) in F_3.

(Table 1) and 2.30 to 6.00 in F_4 generation (Table 2). The F_3 progeny plant No 67/1 recorded highest micronaire (6.20 g/inch) and F_4 progeny plant no 71/5-3 and 71/5-7 recorded higher micrinaire (6.00 g/inch).

Fibre strength (g/tex)

The fibre strength recorded was higher in F_3 generation (29.60 g/tex) than recorded in F_4 generation (26.00 g/tex). The highest fibre strength (29.70) was recorded by progeny plant no (73/14) in F_3 generation and F_4 generation 56/6-2 progeny plant no had high fibre strength (26.00g/tex).

Elongation (%)

The average elongation was 6.29 and 5.98 in F_3 and F_4 generation. The range of elongation varied between 5.10 and 7.00 in F_3 generation (Table 1). While it ranged between 5.10 and 6.10 in F_4 segregating generation (Table 2).

Table 1. Mean, range, standard deviation and coefficient of variation for fibre quality parameters in F_3 generation

	2.5 Span length(mm)	Uniformity ratio	Micronaire	Fibre Strength (g/text)	Elongation
Mean	28.84	47.94	3.36	21.87	6.29
Maximum	36.90	53.00	6.20	29.70	7.00
Minimum	20.00	41.00	2.40	16.70	5.10
S. D. ±	2.90	2.31	0.81	2.40	0.36
CV (%)	10.04	4.81	24.1	10.98	5.75

Table 2. Mean, range, standard deviation and coefficient of variation for fibre quality parameters in F_4 generation

	2.5 Span length(mm)	Uniformity ratio	Micronaire	Fibre Strength (g/text)	Elongation
Mean	28.12	48.59	4.19	22.18	5.98
Maximum	34.60	54.00	6.00	26.00	6.90
Minimum	23.80	42.00	2.30	19.00	5.10
S. D. ±	2.57	2.75	1.08	1.65	0.46
CV (%)	9.15	5.66	25.69	7.43	7.68

Table 3. F_3 **progenies having desirable fibre properties**

Progeny Plant No.	2.5 Span length (mm)	Uniformity ratio	Micronaire	Fibre Strength (g/text)	Elongation
10aab/3	28.6	49	3.8	25.5	6.4
9T/7	32.2	48	3.4	26.0	6.5
9T/1	31.8	49	3.4	26.9	6.5
30A/3	30.4	48	3.6	24.9	6.4
4T/5	35.2	48	3.2	26.6	5.9
73/9	30.7	49	3.2	27.2	6.0
73/6	30.9	48	3.3	25.7	5.7

Table 4. F_4 **progenies having desirable fibre properties**

Progeny Plant No.	2.5 Span length (mm)	Uniformity ratio	Micronaire	Fibre Strength (g /text)	Elongation
56/6-2 (R2T2)	30.00	47.00	2.80	26.00	6.20
4T/5-13(R1T1)	31.70	48.00	3.50	25.30	5.90
9T/3-20(R1T1)	30.20	48.00	3.30	25.10	6.10
13W/9-2(R2T1)	31.10	51.00	3.30	24.70	6.30
45/3-18(R2T1)	34.30	48.00	3.60	25.10	5.70
9aab/8-5 single	34.60	45.00	3.00	24.70	6.00

The F_3 segregating generation showed higher degree of variability for fibre quality traits like fibre length (mm), fibre strength (g/t), micronaire and uniformity ratio (UR). Out of the 189 F_3 plants, 123 plants were found to have span length more than 25, fibre strength more than 21 g/t (Nagrajan and Sreerangaswamy, 1973). In respect of uniformity ratio, 107 plants were found to be superior *i.e.* above 48%. Seven F_3 segregants (Table: 3) *viz.,* 10aab/3, 9T/7, 9T/1, 30A/3, 4T/5, 73/9, 73/6 showed highest performance for the entire fibre quality attributes. Similarly in F_4 generation 48 F_3 progenies were evaluated along with twelve checks on the basis of yield, resistance to sucking pests and fibre quality parameter, F_4 Progeny No 56/6-2, 4T/5-13, 9T/3-20, 13W/9-2, 45/3-18 and 9aab/8-5 (Table: 4) had desirable fibre properties. while progeny No 45/3 recorded better performance for most of the characters studied (Mehetre, 2010). Such type of selection will be useful in future breeding strategies as well as this will help in developing varieties/genotypes with fibre quality parameters as per needs of modern textile and spinning mills). Earlier workers *viz.,* (Mehetre *et al.,* 2005), Kohel and Bell (1999), Deshpande and Baig (2005) have made similar efforts in these directions.

Reviews on distant/intergeneric hybridization in cotton breeding (Mehetre, 1993) and incompatibility in wide hybridization of Gossypium species: colchicine and its use in cotton breeding(Mehetre *et al.,* 2003) a tool to overcome incompatible (Jagtap, P. K. and Mehetre, S.S. 2007) disease and pest resistance(Mehetre *et al.,* 2002a) helped us tremendously in solving problems faced by earlier workers. Thus with the clear-cut planning, blending of conventional and nonconventional techniques, evaluation of fibre quality parameters of lint samples of small quantities and handling of the material, etc. led us to succeed the introgressive breeding. Utilization of *Gossypium anomalum* to impart fineness (low fibre weight) with high maturity to *Gossypium arboreum* L. yielded commendable results. If Bt gene is incorporated into this hybrid, it can be an excellent source of bollworm tolerance coupled with superior fibre properties and yield.

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Multitier cropping systems for resource conservation and higher productivity in eastern ghat highland zone of Odisha

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ABSTRACT

An experiment consisting of five multitier cropping systems comprising square planting (4m x 4m) of two fruit trees (papaya and drumstick), *Gliricidia* or No-*Gliricidia* planting on plot boundary with ginger as intercrop and a control (farmers' practice of broadcast sown fingermillet) was carried out for four years (2007-2010) on 2% sloping land having sandy clayey red lateritic soil in Eastern Ghat Highland zone of Odisha. Planting papaya and drumstick along with ginger arrested the runoff by 6.05 and 5.24% compared to control. *Gliricidia* planted on boundary of papaya + ginger and drumstick + ginger plots decreased soil loss by 8.64 and 7.88 t/ha, respectively, over control. These multitier cropping systems reduced nutrient losses (N, P and K) by about 50%. *Gliricidia* improved ginger yield by 11.5% under papaya + *Gliricidia* and 8.6% under drumstick + *Gliricidia* system over papaya and drumstick sole treatments. Maximum net returns (₹2.29 lakhs ha^{-1}) were obtained from ginger + papaya + *Gliricidia* with benefit: cost ratio of 1.67. Farmers' practice (broadcasting of finger millet) was not found economical as it gave benefit: cost ratio below 1 and allowed higher runoff, soil and nutrient losses.

Key words: Erosion, green-leaf manuring, multitier cropping, nutrient loss, runoff.

Southern Odisha extends over ten districts of the state (6.6 M ha area) falling under Eastern Ghats region of India and feeds 12.8 million population (Anonymous, 2011). The land holdings in the region are predominantly small and marginally splitted up across three distinct types of arable landscapes viz. uplands, medium and low lands. Topographically, medium lands are located between shifting cultivation affected uplands and low (*Jhola*) lands. Both uplands and medium lands are subjected to severe degradation by water erosion and thus produce very low crop yields. This has posed a serious threat to the food, economic and livelihood securities of the people. A considerable portion of medium and uplands remains fallow despite being potential for supporting integrated production system under plentiful rainwater availability. Hence, vertically diversified alternative land uses (*i.e.* multitier cropping system), which is lacking for the region is envisaged to establish higher production and ensure food, nutrition and economy security. Keeping above points in view, viable multitier cropping systems were designed and experimented to study their effects on runoff, soil, nutrient losses, soil fertility and overall production in the study region.

MATERIALS AND METHODS

The field experiment was conducted at the Research Farm of Central Soil and Water Conservation Research and Training Institute, Research Centre, Sunabeda (latitude 19° 45' 30" N, longitude 82° 56' E and altitude 950 m above mean sea level) in Koraput District of Odisha, during *Kharif* seasons of 2007-10. Soil of the study site was red lateritic Ustocherpets, sandy clay loam in texture and acidic in nature. Soil of experimental site was low in organic C (0.39%), available phosphorus (16.7 kg/ha) and high in available potassium (253.2 kg/ha). The experiment had five treatments consisting of the combinations of two fruit trees; papaya (*Carica papaya*) and drumstick (*Moringa oleifera*) with boundary plantation of one forest shrub i.e. *Gliricidia sepium* at one meter plant to plant distance. Papaya and drumstick were planted with row to row and plant to plant spacing of 4m distance Ginger (*Zingiber offcinale*) was taken up as test intercrop. Farmers' practice of broadcast sowing of finger millet (*Eleusine coracana*) was taken as control for comparison of treatments. The treatments were set in a randomized complete block design (RBD) replicated thrice run off and soil losses were estimated using multi-slot divisors. The statistical analysis was carried out using the ANOVA procedures of RBD.

Each experimental plot was 12 m wide and 18 m long on a terraced land having 2 per cent slope. The test crop (Ginger) was sown on raised beds (10 m, 1 m and 0.15 m) during first week of July every year at recommended spacing of (25 x 20 cm) on beds laid across the slope. The crop was grown under rainfed conditions supplied with 125 Kg N, 100 kg P_2O_5 and 100 K_2O kg/ha. In control plots, finger millet was sown by broadcast method with application of basal dose of 20 N kg/ha. *Gliricidia* shrubs were regularly pruned at one-meter height when it attained the height of 1.5 m and were maintained uniformly around the plot and leaves collected thereof were used for green-leaf manuring. Rainfall intensity and daily rainfall were collected from CSWCRTI Research Center's meteorological observatory. Organic C, available phosphorus and potassium content in soil and runoff sediment samples were determined using standard procedures. Biophysical parameters and yield data of papaya and drumstick was recorded at the time of maturity. Economics was worked out based on current (2012) market prices and wage rates of the region.

Results and Discussion

A total of 835.6, 790.8, 756.8 and 1,162 mm rainfall was recorded in 54, 44, 37 and 59 rainy days during the crop season of 2007, 2008, 2009 and 2010, respectively. Runoff and soil loss was significantly affected by different treatments (Table 1). Square plantation of papaya and drumstick in ginger crop reduced net runoff by 6.05 and 5.24% in comparison to finger millet broadcasting, (farmers' practice). This can be attributed to better rainfall interception by these fruit tree species, which also created physical barrier in smooth flow of runoff. In *Gliricidia* based papaya and drumstick treatments, soil loss reduced by 8.56 and 7.80 t/ha in comparison to farmers' practice (15.7 t/ha). The reason can be reduced runoff and anchorage of soil by roots of the tree species. In addition, *Gliricidia* planted along the boundary of the plots had significant impact on reduction of soil loss by 2.27 and 2.03 t/ha compared to papaya and drumstick in their sole plantation. It occurred as the canopies of hedge row reduced the kinetic energy of the rains (Velumurgun *et al.*, 2008). Pandey and Chaudhary (2010) reported that *Gliricidia* hedgerows in vegetable cultivation and as cover crop in coconut plantation reduced soil loss by 61%.

In finger millet broadcasting, organic C, available phosphorus (P) and potassium (K) lost to the magnitude of 73.08, 0.146 and 2.02 kg/ha year^{-1} during four years of experiment, which was significantly higher than other treatments. The higher magnitude of soil loss was responsible for greater losses of Organic C under finger millet cultivation than other multitier cropping systems. Loss of available P was negligible and it is probably due to fixation of P in acidic soil. However, in comparison to finger millet broadcasting, the loss of organic C, P and K reduced by 47.60, 54.79 and 45.54% in papaya + *Gliricidia* and by 44.84, 59.58 and 44.05% in drumstick + *Gliricidia* system. The reason could be that the addition of organic matter by lopping of *Gliricidia* planted in field bunds provided available nutrients to crop (Wani *et al.*, 2003).

Economical analysis was carried out taking all the components of individual multitier cropping system with ginger as intercrop. Cost of ₹880 is required more when *Gliricidia* is included in the sole cultivation of papaya and drumstick. However, it increased yield of *papaya* by 1.8 q/ha and of drumstick by 0.9 q/ha. Therefore, the highest net returns were

Table 1. Effect of different multitier cropping systems on resource conservation parameters and economics in ginger (Pooled data of 2007 - 10)

Treatment	Runoff (%)	Runoff (mm)	Soil loss (t/ha)	Organic Carbon	Available Phosphorus	Available Potassium	Fruit yield	Ginger yield	Cost of Cultivation	Net returns	B:C ratio
				Nutrient loss (kg/ha)			(t /ha)		₹/ha		
Papaya	15.61	142.1	9.41	47.20	0.088	1.41	6.09	11.8	136,978	123,883	0.90
Papaya + *Gliricidia*	12.89	117.6	7.14	38.29	0.066	1.10	6.27	13.7	137,638	229,943	1.67
Drumstick	16.42	149.1	9.93	52.03	0.093	1.60	1.46	12.4	132,453	194,443	1.47
Drumstick + *Gliricidia*	13.88	126.7	7.90	40.31	0.059	1.13	1.55	13.6	133,113	224,863	1.69
Finger millet broad cast sown (Farmers' practice)	21.66	194.8	15.7	73.08	0.146	2.02	--	7.3*	4,648	1,193	0.26
CD at 5%	2.05	17.4	1.58	9.11	0.013	0.18	--	--	5,533	12,151	--

*Finger millet yield, Market prices (2012) Papaya- ₹ 400/q, Drumstick- ₹ 1200/q, Ginger- ₹ 2000/q, Finger millet- ₹ 800/q associated with papaya + *Gliricidia* system for ginger cultivation, which are ₹2.29 lakhs/ha. Cost of cultivation was also found maximum (₹1.37 lakhs/ha) in this system with benefit: cost ratio of 1.67. Initial cost of cultivation of multitier cropping system was higher than the farmers' practice of finger millet broadcasting, but in the subsequent years it was found much more remunerative. Farmers' practice of broadcasting of fingermillet was not found economical as it gave benefit: cost ratio below 1.

Results from the study revealed that multitier cropping system is more remunerative than the prevailing farmers' practice of fingermillet broadcasting. Inclusion of *Gliricidia* and fruit tree in multitier cropping system improves soil health and reduces soil erosion, which is a serious issue in red lateritic soils of Eastern Ghat High land Zone of Odisha.

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Heritability and genetic advance in vegetable pea (*Pisum sativum L.*)

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ABSTRACT

Ten pea genotypes crossed in a diallel mating design excluding reciprocals were evaluated with their 45 F_1's along with parents in a randomized block design in three replications at the Department of Vegetable Science, C.S. Azad University of Agriculture and Technology, Kalyanpur, Kanpur, during winter season 2007-08. The heritability and genetic advance were studied for all the traits under study. The estimates of heritability varied from 9.12 % (pod width) to 63.25% (number of first fruiting node). The heritability estimates were moderate for pod length and shelling percentage; low for pod width and ash content. For remaining characters, estimates of heritability were high. Genetic advance was highest for number of pods per plant while four characters viz. plant number of pods per plant, plant height, length to first fruiting node and days to flowering showed high genetic advance (more than 30%), while pod width showed lowest genetic advance. Other traits showed moderate genetic advance. The consequences of heritability coupled with genetic advance showed that four characters *viz.* number of pods per plant, plant height, length to first fruiting node and days to flowering had high heritability as well as high genetic gain, thus, these characters may be improved through selection method.

Key words : Heritability, genetic advance, vegetable pea.

Garden Pea (*Pisum sativum* L.) is a very common nutritious vegetable grown in cool season throughout the world. Peas are highly nutritious and contain high percentage of digestible protein (7.2%) alongwith carbohydrate, vitamins and mineral matters. It is commercially grown as winter crop in North India, widely consumed and most relished in various forms (Das *et al.*, 1992). Heritability indicates the proportion of phenotypic variance that is due to genotypes which is heritable. It serve as a useful guide to breeders as the selection for trait having high heritability will be effective and improvement will be brought through selection. The genetic advance is an improvement in the genetic value new population as compared to original one. It will be possible to decide various breeding programmes for improvement of different characters based on the study of heritability and genetic advance.

MATERIALS AND METHODS

A set of ten genotypes of pea namely Azad Pea-1, K.S.-150, K.S.-175, K.S.-156, P.M.R.-19, P.M.R.-20, Azad Pea-4, T.D.C.-1, Azad Pea-3 and E-6 were crossed in a diallel mating design excluding reciprocals. All the 45 F_1's along with parents were sown in a randomized block design with three replications at the Department of Vegetable Science, C.S. Azad University of Agriculture & Technology, Kalyanpur, Kanpur, during winter season 2007-08. Observations were recorded on ten randomly selected plants from each treatment for ten quantitative characters *viz.* days to flowering, days to maturity, plant height (cm), length of first fruiting node (cm), number of first fruiting node, pod length (cm), pod width (cm), number of seeds per pod, green pod yield per pod (g) and four qualitative traits *viz.* shelling percentage, total crude protein (%), dry matter content (%), ash content (%). Data were collected and subjected to statistical analysis. The estimates of heritability were calculated as per the method suggested by Crumpacker and Allard (1962) and the heritability and genetic advance were studied for all the traits under study.

Table 1. Heritability, genetic advance & genetic advance in percent over mean for 14 characters in 10X10 diallel cross in vegetable pea

S.No.	Characters	Population	Heritability mean	G.A.	G.A. in % over mean
1.	Days of flowering	42.14	62.16	12.66	30.04
2.	Days to maturity	65.87	50.28	16.77	25.46
3.	Plant Height (cm)	64.07	39.37	28.32	44.20
4.	Length of first fruiting node (cm)	30.75	52.39	12.40	40.33
5.	Number of first fruiting node	11.78	63.25	3.06	25.98
6.	Number of pods/ plant	14.90	39.01	6.89	46.24
7.	Pod length (cm)	9.05	25.18	1.85	20.44
8.	Pod width (cm)	1.31	9.12	0.07	5.34
9.	Number of seeds/pod	8.29	37.91	1.84	22.20
10.	Shelling (%)	47.18	27.91	9.21	19.52
11.	Total crude protein content (%)	19.00	34.75	3.11	16.37
12.	Dry matter content (%)	26.93	49.05	3.35	13.55
13.	Ash content (%)	3.79	9.63	0.96	25.33
14.	Green Pod Yield (g)/plant	86.87	57.01	23.48	27.03

In order to facilitate the description of estimates of heritability, the reckoned values of estimates were classified into three categories by Robinson (1965). If the estimated value of heritability is below 10% it will be said to be having low heritability, while if heritability ranged between 10-30% then medium heritability but if it is greater than 30% it would be highly heritable.

RESULTS AND DISCUSSION

The estimates of heritability and genetic advances for 14 attributes are presented in Table 1. The estimates of heritability varied from 9.12 % (pod width) to 63.25% (number of first fruiting node). The heritability estimates revealed low for pod width and ash content; moderate for pod length and shelling percentage while high for remaining traits *viz.* days to flowering, days to maturity, plant height, length of first fruiting node, number of first fruiting node, number of seeds per pod, total crude protein, dry matter content and green pod yield per plant.

The number of pods per plant recorded highest value of genetic advance (46.24%) followed by plant height (44.20%), length of first fruiting node (40.33%), days to flowering (30.04%), green pod yield/plant (27.03%), number of first fruiting node (25.33%), number of seeds/pod (22.20), Pod length (20.44%), shelling % (19.52%), total crude protein content (16.37%), dry matter content (13.55%) and lowest for pod width (5.34%).

Four characters of plant *viz.* plant number of pods per plant, plant height, length to first fruiting node and days to flowering showed high genetic advance (more than 30%), while pod width showed lowest genetic advance. Other traits showed moderate genetic advance.

The other works also reported high to low heritability and genetic advance for different traits in vegetable pea (Rai *et al.* (2006), Mahamad *et al.* (2006), Gupta *et al.* (2006), Sharma *et al.* (2007) and Singh *et al.* (2007).

The consequences of heritability coupled with genetic advance showed that four characters viz. number of pod per plant, plant height, length to first fruiting node and days to flowering had high heritability as well as high genetic gain. Thus, these characters may be improved through selection method. The trait pod width showed low heritability coupled with low genetic advance and so selection would be ineffective for pod width. Pod length and shelling percentage showed moderate heritability coupled with moderate genetic advance. Traits days to maturity, number of first fruiting node, number of seeds per pod, total crude protein (%), dry matter content (%) and green pod yield per plant showed high heritability coupled moderate genetic advance. Ash content showed low heritability coupled with moderate genetic advance. Thus selection may not be rewarding for pod length, shelling percentage, days to maturity, number of first fruiting node, number of seeds per pod, total crude protein (%), dry matter content (%) and green pod yield per plant therefore other breeding methods should be taken for improvement of these traits.

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Yield gap analysis in rice, wheat and pulses in India

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ABSTRACT

The study has critically examined the state-wise yield gap, correlation between state average yield, share of irrigated area and fertilizer consumption (kg/ha) in rice, wheat and pulses in major producing states. The farmers' perception on state specific constraints in rice production are also analysed. The results showed that there were substantial yield gaps ranged from 4-60% in rice; 3-54% in wheat; and 6-202% in chickpea and pigeonpea between improved and check varieties at farmers' field in major producing states. There are positive correlation between state average yield and seed replacement rate, share of irrigated area and fertilizer consumption in rice, wheat, chickpea and pigeonpea (except between state average yield and share of irrigated area under chickpea and pigeonpea crop). It is suggested that to bridge the yield gap in rice, wheat and pulses, there is need of district level information on seed replacement rate of these crops. If district with low seed replacement rate and lower yield need special attention for yield improvement by adoption of the improved varieties and it will be economical and suitable policy option to bridge the yield gap in these crops. If seed replacement rate is at desired level (25% for self pollinated crops and 35% for cross pollinated crops) emphasis should given to increase irrigated area and fertilizer consumption and identify the other constraints and judicious measures use to remove on the basis of severity of the constraints.

Key words : Yield gap, seed replacement rate, fertilizer consumption, irrigated area, yield constraints

Rice, wheat and pulses are backbone of the food security of our country. These foodgrains constitute 37% of the total food consumption expenditure in the rural India, in spite of rapid increase in consumptions of high value commodities such as milk, egg, fish, fruits and vegetables, etc. (CSO, 2011). The total production of rice, wheat and pulses were 96, 87 and 18 million tonnes and yields 2.3, 3.0 and 0.69 t/ha respectively during 2010-11 in India. The projected total domestic demand for rice, wheat and pulses to be 113.3, 89.5 and 19.5 million tonnes for the year 2021-22 (Kumar, *et al.,* 2009). In spite of the implementation of 'National Food Security Mission (2007)' to increase the production of 10 million tonnes of rice, 8 million tonnes of wheat and 2 million tonnes of pulses by the end of Eleventh Plan (2007-08 to 2011-12), the production has increased by only 2.6 million tonnes for rice, 11.1 million tonnes for wheat and 4.0 million tonnes for pulses in the year 2010-11 in comparison to base year 2006-07. The annual compound growth rates (ACGR) for area of rice, wheat and pulses were estimated as -1.0%, 1.0% and 2.4%; for production -0.3%, 3% and 5.1%; and for yield 0.8%, 2.0 % and 2.6% respectively during 2006-07 to 2010-11.

To achieve the target of desired production, the yield gap analysis is a useful guide to establish research priorities for rice, wheat and pulse crops through knowledge of yield limiting factors and their influence on yield (Singh, 2001). Therefore, keeping in view the present study attempts to analyse the yield gaps and correlation between state average yield, share of irrigated area and fertilizer consumption (kg/ha) in rice, wheat and pulses in major producing states along with state specific constraints in rice production and suggest appropriate policy options to bridge the yield gap in rice, wheat and pulses in India.

MATERIAL AND METHODS

The yield gap is the difference between yield obtained at the nearest demonstration plot and average yield obtained at farmers' field in a particular region. The study is based on secondary data, which were collected from various publications from Directorate of Rice Development, Patna, Agriculture Census Division, Directorate of Economics and Statistics, Ministry of Agriculture, Government of India and Directorate of Rice Research, Hyderabad, Directorate of Wheat Research, Karnal and Indian Institute of Pulses Research, Kanpur.

RESULTS AND DISCUSSION

Yield gap, seed replacement rate, irrigated share and fertilizer consumption in rice

The status of yield gap, seed replacement rate, irrigated share and fertilizer consumption under the rice in major producing states is depicted in Table 1. It reveals that there is substantial yield gap ranging from 4% to over 60% between improved and check variety at farmers' field. The maximum yield gap was estimated in the state of Jharkhand (2.4) followed by Tamil Nadu (1.5) and Uttar Pradesh (1.9). Moreover, there was huge yield advantage of improved variety over the state average yield ranging from over 80% in West Bengal to 500% in Jharkhand. There are strong positive correlation between state average yield and seed replacement rate (0.84), share of irrigated area under rice (0.82) and fertilizer consumption (kg/ha) in rice (0.95). It implies that yield gap would be reduced by enhancing seed replacement rate, using improved varieties, expansion of irrigated area and by increasing fertilizer consumption in rice crop.

Table 1. Yield gap, seed replacement rate, irrigated share and fertilizer consumption under the rice in major producing states in India, 2007-08

State	Ecosystem	Yield of improved variety	Yield of check variety	%Yield gap between improved and check	State average yield	%Yield advantage of improved variety over state average yield	%Seed replace ment rate	%coverage area under irrigation in rice	Fertilizer consump tion (NPK) in rice (kg/ha) 2006-2007
West Bengal	Irrigated	4.1	4.0	4	2.3	83	27	48	109
Uttar Pradesh	Irrigated	7.8	5.9	33	2.2	259	25	77	144
Chhattisgarh	Shallow lowlands	3.9	3.4	14	1.1	256	12	33	39
Andhra Pradesh	Upland	5.6	4.9	15	2.7	110	73	97	222
Bihar	Shallow lowlands	5.0	4.1	13	1.5	227	15	57	159*
Assam	Shallow lowlands	4.6	3.2	41	1.5	211	17	4	62
Tamil Nadu	Irrigated	7.1	5.6	27	3.3	116	65	93	244
Maharashtra	Upland	3.8	3.3	13	1.7	124	42	26	103*
Jharkhand	Upland	6.1	3.7	66	1.0	498	12	6	55*
Karnataka	Irrigated	5.8	4.9	18	2.5	137	36	74	237
Gujarat	Irrigated	4.5	4.2	7	1.5	204	20	57	106

Source: Frontline Demonstrations on Rice (2007-08), Directorate of Rice Research, Rajendranagar, Hyderabad; Agricultural Statistics at a Glance, 2010, Directorate of Economics and Statistics, All India Report on Input Survey, 2006-07, Agriculture census Division, Ministry of Agriculture, Government of India.

Note: * indicates fertilizer consumption to gross cropped area (kg/ha) as input survey was not conducted in Bihar, Jharkhand and Maharastra.

Categorization of the districts on the basis of productivity of rice

The categorization of the districts on the basis of productivity of rice in major rice growing states is presented in Table 2. It reveals that only 20% of the districts belongs to high productivity category (> 2.5t/ha) and none of the districts from the state of Orissa, Chhattisgarh, Assam, Madhya Pradesh, Jharkhand and Gujarat reached under this category. The share of Medium productivity districts (2.0-2.5t/ha), Medium-low productivity districts (1.5-2.0 t/ha), Low productivity districts (1.0-1.5t/ha) and Very low productivity districts (< 1.0t/ha) were estimated as 18%, 21%, 25% and 15% respectively at all India level. The productivity of more than 60% of the districts were less than national average (< 2.0t/ha). Hence, there are ample scope to enhance productivity over 60% of the districts by removing the specific yield limiting factors for various agro-ecological situations in India.

Table 2. Categorization of the districts on the basis of productivity of rice in major growing states in India during 2002-07

State	High productivity districts (> 2.5t/ha)	Medium productivity districts (2.0-2.5t/ha)	Medium-low productivity districts (1.5-2.0 t/ha)	Low productivity districts (1.0-1.5t/ha)	Very low productivity districts (< 1.0t/ha)	Productivity below the average (< 2.0t/ha)
West Bengal	8	7	3	0	03	03
Uttar Pradesh	5	31	25	6	3	35
Orissa	0	0	8	20	2	30
Chhattisgarh	0	0	4	12	0	16
Andhra Pradesh	14	6	2	0	0	2
Bihar	1	2	7	18	10	35
Punjab	19	0	0	0	0	0
Assam	0	1	11	12	2	25
Tamil Nadu	25	2	2	0	0	2
Madhya Pradesh	0	2	2	6	34	42
Maharashtra	1	5	1	10	15	26
Jharkhand	0	3	11	7	1	19
Karnataka	11	11	1	2	2	5
Haryana	12	4	3	0	0	3
Gujarat	0	5	6	2	3	11
Kerala	1	10	2	1	0	3

Source: Directorate of Rice Development, Patna, Ministry of Agriculture, Government of India.

Yield gap, seed replacement rate, irrigated share and fertilizer consumption in wheat

The scenario of yield gap and rate of seed replacement, irrigated share and fertilizer consumption in wheat in major growing states is shown in Table 3. It reveals that there are substantial yield gaps ranging from 3% in Punjab and Haryana to 54% in Madhya Pradesh between improved and check variety at farmers' field. Moreover, there are huge yield advantages of improved varieties over the state average yield ranging from over 8% in West Bengal to 323% in Karnataka. The rates of seed replacement are lower than national average (18%) and below the desired rate of replacement for wheat crop (25%) in most of the states. The correlation between state average yield and seed replacement rate, share of irrigated area and fertilizer consumption in wheat crop found as 0.06, 0.65 and 0.73 respectively. It implies that

Table 3. Yield gap, seed replacement rate, irrigated share and fertilizer consumption under the wheat in major producing states in India, 2007-08

State	Yield of improved variety	Yield of check variety	%Yield gap between improved and check variety	State average yield	%Yield advantage of improved variety overstate average yield	%Seed replacement rate	%coverage area under irrigation in wheat	Fertilizer consumption (NPK) in wheat (kg/ha),2006-2007
Uttar Pradesh	4.6	4.1	13	2.8	63	27	98	177
Punjab	4.9	4.7	3	4.5	9	19	100	265
Haryana	4.9	4.8	3	4.2	17	24	100	223
Rajasthan	4.2	3.8	10	2.8	54	26	99	101
Madhya Pradesh	3.9	2.5	54	1.6	142	18	84	103
Bihar	4.0	3.2	26	2.1	93	15	92	159*
Gujarat	4.6	4.4	5	3.0	53	24	90	304
Maharashtra	3.6	3.1	17	1.7	119	42	75	103*
West Bengal	2.8	2.2	28	2.6	8	38	74	143*
Uttarakhand	3.5	2.9	19	2.1	69	22	53	137
Himachal Pradesh	2.4	2.2	13	1.4	77	14	19	48
Jammu & Kashmir	2.1	1.8	19	1.8	21	12	28	46
Karnataka	4.0	3.4	17	1.0	323	12	52	121*
Jharkhand	3.8	2.7	41	1.6	135	9	86	55*
Assam	2.6	2.1	24	1.3	104	47	1	155

Source: Annual Report-2008-09, Directorate of Wheat Research, Karnal, Indian Council of Agricultural Research and Agricultural Statistics at a Glance, 2010, Directorate of Economics and Statistics, All India Report on Input Survey, 2006-07, Agriculture census Division, Ministry of Agriculture, Government of India.

Note: * indicates fertilizer consumption to gross cropped area (kg/ha) as input survey was not conducted in Bihar, Jharkhand and Maharashtra; and data on wheat crop not available for the state of Karnataka and West Bengal.

yield should be enhanced by increasing in fertilizer consumption and expansion of irrigated area in wheat crop along with use of improved varieties in those states having lower seed replacement rate

Categorization of the districts on the basis of productivity of wheat

The wheat growing districts in various states are categorized on the basis of productivity presented in Table 4 showed that the productivity of all the districts of Punjab were above the 2.5 t/ha (high productivity) while none of the districts from Bihar and Himachal Pradesh included in the high productivity category. The share of High productivity districts (> 2.5t/ha), Medium productivity districts (2.0-2.5t/ha), Medium-low productivity districts (1.5-2.0 t/ha), Low productivity districts (1.0-1.5t/ha) and Very low productivity districts (< 1.0t/ha) were 43%, 21%, 21%, 9% and 6% respectively. Moreover, the productivity of the 69% of the districts are below the national average (2.8 t/ha). The state of Madhya Pradesh ranks first followed by Bihar, Uttar Pradesh and West Bengal in respect of maximum number of districts having productivity level less than national average. It implies that districts having less productivity than national average should given priority for yield enhancement of wheat by removing constraints in particular district.

Yield gap, seed replacement rate, irrigated share and fertilizer consumption in chickpea and pigeonpea

The yield gap in chickpea and pigeonpea

Table 4. Categorization of the districts on the basis of productivity of wheat in major growing states in India during 2007-08

State	High productivity districts (> 2.5t/ha)	Medium productivity districts (2.0-2.5t/ha)	Medium-low productivity districts (1.5-2.0 t/ha)	Low productivity districts (1.0-1.5t/ha)	Very low productivity districts (< 1.0t/ha)	Productivity below the average (< 2.08t/ha)
Uttar Pradesh	51	10	6	2	1	37
Punjab	17	0	0	0	0	0
Haryana	18	1	0	0	0	1
Rajasthan	16	9	4	2	1	21
Madhya Pradesh	6	11	17	4	11	45
Bihar	0	12	18	8	1	39
Gujarat	19	3	1	0	0	15
West Bengal	1	10	8	0	0	19
Uttarakhand	2	2	1	5	3	12
Himachal Pradesh	0	1	6	5	0	12
Jammu & Kashmir	4	5	3	3	3	13

between improved and check varieties along with seed replacement rate, irrigated share and fertilizer consumption in major pulses growing states is presented in Table 5. It reveals that the maximum yield gap is observed in the state of Jharkhand, followed by Bihar and Odisha in chickpea, while Orissa ranks first, followed by Uttar Pradesh and Madhya Pradesh in case of pigeonpea. The yield advantage of improved varieties over state average is highest in Haryana followed by Madhya Pradesh and Rajashtan in chickpea, while Chatisgarh ranks first, followed by Madhya Pradesh and Uttar Pradesh in pigeonpea.

It is also observed that the rate of seed replacement in pulse crops is far below in most of the states and even at the national level (10% for chickpea and 11% for pigeonpea) which is also much below the desired level of seed replacement for pulse crops (25% for self pollinated crops like chickpea and between 25-35 % for pigeonpea as often cross pollinated crop). The correlation between state average yield and seed replacement rate, irrigated area and fertilizer consumption were 0.60, -0.22 and 0.52 respectively in chickpea and pigeonpea. It implies that yield gap should minimize by increasing in seed replacement rate and adoption of suitable improved varieties and consumption of fertilizer, however, irrigated area under these two crops showed negative impact on yield.

Farmers' perceptions and factors affecting low yield in rice

The farmers' perceptions on constraints responsible for yield gap in major rice growing states are presented in Table 6. It shows that soil needs amendments, followed by lack of drainage facility, resistant varieties and lack of credit facilities were major constraints in state of Andhra Pradesh. In state of Assam, poor irrigation facility, followed by lack of credit facilities, disease and other pest infestation and lack of drainage facilities were reported major constraints. Lack of credit facilities ranked first, followed by inadequate fertilizer application, non-availability of hybrid seed, inadequate availability of good varieties and lack of technical support were reported major constraints in state of Bihar. In the state of Chhattisgarh, Inadequate availability of good varieties, followed by varieties available but susceptible to diseases and inadequate fertilizer application were reported as major constraints. The half of the respondents reported that disease and other pest infestation were main constraint in rice production in state of Haryana. The respondents of Odisha state reported that need of soil amendment, followed by lack of technical support and inadequate fertilizer application were major constraints. The inappropriate and inadequate fertilizer application and inadequate availability of good

Table 5. Yield gap, seed replacement rate, irrigated share and fertilizer consumption under the Chickpea and Pigeonpea in major producing states in India, 2007-08

State	Crop	Yield of improved variety, TE 2005	Yield of check variety TE 2005	% Yield gap between improved and check variety	State average yield (2007-08)	% Yield Advantage of improved variety over state average yield	% Seed replacement rate	% coverage area under irrigation in Chickpea and Pigeonpea	Fertillizer consumption (NPK) in Chick Chickpea and Pigeonpea kg/ ha), 2006-07
Maharashtra	Chickpea	1.58	1.21	31	0.83	90	16	26	103*
	Pigeonpea	1.10	0.89	24	0.92	20	20	2	103*
Madhya Pradesh	Chickpea	2.04	1.46	40	0.71	187	3	53	50
	Pigeonpea	1.53	1.15	33	0.67	128	4	1	20
Andhra Pradesh	Chickpea	2.22	1.95	14	1.45	53	56	2	109
	Pigeonpea	1.18	0.91	30	0.65	82	34	1	69
Uttar Pradesh	Chickpea	1.69	1.39	22	0.75	125	15	14	7
	Pigeonpea	1.90	1.30	46	0.89	113	19	14	3
Rajasthtan	Chickpea	1.24	0.94	32	0.47	164	5	42	13
Karnataka	Chickpea	1.22	1.01	21	0.61	100	18	17	38
	Pigeonpea	1.12	0.93	20	0.71	58	15	4	71
Gujarat	Chickpea	1.45	1.15	26	0.98	48	15	35	38
	Pigeonpea	2.01	1.59	26	1.11	81	17	8	92
Chhatisgarh	Chickpea	1.33	1.60	20	0.87	84	12	25	36
	Pigeonpea	1.76	1.34	31	0.52	238	7	1	21
Bihar	Chickpea	1.15	0.67	72	0.97	19	10	12	159*
	Pigeonpea	1.80	1.67	8	1.01	78	4	1	159*
Odisha	Chickpea	0.79	0.51	55	0.66	20	25	1	27
	Pigeonpea	0.99	0.65	52	0.83	19	1	1	6
Jharkhand	Chickpea	1.13	0.50	126	0.80	41	3	3	55*
Tamil Nadu	Pigeonpea	0.74	0.60	23	0.70	6	10	3	32
Haryana	Chickpea	1.54	1.27	21	0.51	202	11	36	28
	Pigeonpea	1.48	1.38	7	1.23	20	54	15	29

Source: Frontline Demonstrations on Pulse Crops (2002-05), Indian Institute of Pulses Research, Kanpur; Agricultural Statistics at a Glance, 2010, Directorate of Economics and Statistics, All India Report on Input Survey, 2006-07, Agriculture census Division, Ministry of Agriculture, Government of India.
Note: * indicates fertilizer consumption to gross cropped area (kg/ha) as input survey was not conducted in Bihar, Jharkhand and Maharashtra; and data on wheat crop not available for the state of Karnataka and West Bengal.

Table 6. Farmers' perceptions of constraints responsible for yield gap in major rice growing states in India, 2003-04.

(Percent)

Constraints	States									
	Andhra Pradesh	Assam	Bihar	Chhattis garh	Haryana	Odisha	Uttar Pradesh	West Bengal	Tamil Nadu	All states
Inadequate availability of good varieties	20	1	88	81	0	18	54	91	50	47
Varieties available but susceptible to disease	78	0	8	63	0	14	2	80	0	39
Non-availability of hybrid seed	53	3	92	50	0	14	11	39	0	32
Fertilizers of required formulation not available	3	0	67	6	0	14	0	0	0	7
Fertilizer application inappropriate	6	0	88	13	0	23	81	5	25	23
Fertilizer application inadequate	67	3	92	56	0	41	65	10	50	40
Land requires leveling	11	1	0	0	0	18	2	0	0	3
Soil needs amendment	98	10	0	13	0	91	4	37	0	35
Lack of drainage facility	89	14	0	0	0	23	14	39	0	31
Poor irrigation facility	2	44	0	19	0	18	5	3	0	12
Lack of technical support	3	0	79	13	0	68	0	0	0	12
Disease/pest infestation	2	23	8	44	50	18	4	95	50	37
Lack of credit facilities	73	43	92	0	0	18	4	76	25	48
Others	3	64	4	13	50	9	14	0	0	20

Note: The sum of constraints in a particular state not necessary equal to 100.

Source: Frontline Demonstrations on Rice (2003-04), Directorate of Rice Research, Indian Council of Agricultural Research, Rajendranagar, Hyderabad.

varieties were major constraints in state of Uttar Pradesh. The disease and other pest infestation, inadequate availability of good varieties and lack of resistant varieties were major constraints identified in state of West Bengal. The halves of the respondents were reported that inadequate availability of good varieties, inadequate fertilizer application and disease/ pest infestation were major constraints in rice production in state of Tamil Nadu.

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Ground water recharge from a lined watercourse under shallow water table condition

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Abstract

The study was conducted to quantify the field groundwater recharge dynamics. Rise and fall in water table were observed in observation wells at orthogonal distances X = 5, 25, 50 and 100 m from a 7 year old cement lined channel (Width = 0.6 m, Water depth = 0.37 m, Design discharge = 0.23 m^3/s) at different time intervals. The initial water table was at 2.54 m depths from soil surface. The height of the bottom of the watercourse (H_o) from the water table was 2.43 m.

Ground water rise R and groundwater fall F increased with time at all orthogonal distances X and followed the square root time law with r^2 values more than 0.95 ($R = 0.0366\ t^{1/2} + 0.03514$; $F = -0.0474\ t^{1/2} + 0.0754$ for 5 m). The watercourse influencing orthogonal reach (the value of X at which rise is more than 14 % of the total rise at 5 m) was 100 m. Groundwater rise rate RR and falling rate FR decreased with time following inverse square root law with r^2 values equals to 0.765 for X=5 m. Seepage from watercourses was mainly a horizontal infiltration phenomenon under shallow water table condition. The ground water rise and fall decreased with distance exponentially with r^2 value more than 0.93 ($R= 0.4092\ e^{-0.0192\,X}$ and $F = 0.5505\ e^{-0.0114X}$). Groundwater rise R was higher than groundwater fall up to 100 hours and then the order was reversed i.e. fall was larger than rise at time more than 100 hours. The practical applications are that lined watercourses contribute to the considerable seepage and ground water recharge up to a canal reach of 100 m even in the short time interval of 170 hours.

Keywords: Ground water recharge, lined watercourses, shallow water table.

With the introduction of canal irrigation system in Haryana the groundwater table had risen to less than 1.5 m from surface soil. This had created the twin problems of water logging and soil salinization. This is seriously affecting the sustainability of irrigated agriculture. Thus in order to conserve water resources, canal and watercourses have been lined at very huge costs; covering 5000 watercourses of 20,000 km length in state of Haryana, India alone (Master Plan, 1998). The seepage could be an effective and eco-friendly measure for groundwater recharge in falling water table situations even after lining of watercourses (Anonymous, 1984) and on the other hand this had also helped in lowering the water table to some extent in shallow water table condition by conjunctive use of saline groundwater and seeped good quality water from the canal.

A few studies have been conducted to quantify the seepage effect and groundwater recharge from ephemeral (Abdulrazzak and Seytoux, 1983), perennial rivers (Knappe *et al.*, 2000) and unlined canals and watercourses (Phogat *et al.*, 2000 and Malik and Richter, 2000). To our knowledge a little information is available

(Rohwer and Stout, 1948) on quantification of groundwater recharge from lined watercourses. Therefore, the present study was conducted to quantify the groundwater recharge dynamics from the lined watercourse under shallow water table condition.

MATERIALS AND METHODS

A field experiment was conducted on a 7-year-old cement lined rectangular watercourse (width 2W = 0.6 m; constant water head h_o = 0.37 m; design discharge = 0.023 m^3/h) in the year 2006-2008 situated at an outlet number - RD 5500 L of farm canal at soil research farm CCS Haryana Agricultural University, Hisar. Soil samples from different layers taken during the installation of observation wells were analyzed for different physico-chemical properties. using standard methods (Table 1).

The initial water table was at 2.54 m depth from the soil surface. The height of the bottom of the watercourse H_o from the water table was 2.43. The saturated aquifer thickness e was 11.6 m and height of the bottom of the watercourse from the soil surface hs was - 0.11 m as shown in Fig. 1(a).

Rise and fall in water table were observed as a function of time t in observation wells O_5, O_{25}, O_{50} and O_{100} placed at watercourse orthogonal distances X = 5, 25, 50 and 100 m as shown in Fig. 1(b) at different time intervals starting from t = 2 h and 6 h for rise and fall respectively. Time t = 0 was taken just before the onset of water flow in the channel for water table rise R; and just after the closure of water flow for water table fall F respectively. Water table rise rate RR = dR/dt and falling rate FR = dF/dt at any certain time t were estimated by numerically differentiating R and F w.r.t. t by the central finite difference method (Forsythe and Warrant, 1960).

Table 1. Relevant soil physico-chemical properties of Hisar lithology

Depth (m)	EC (dsm^{-1})	pH	Texture	k cm/h
0.0-9.6	1.2	8.2	Loam	0.628
9.6-12.8	1.19	8.5	Loamy sand	1.29
12.8-24.3	0.96	8.6	Clay loam	0.633

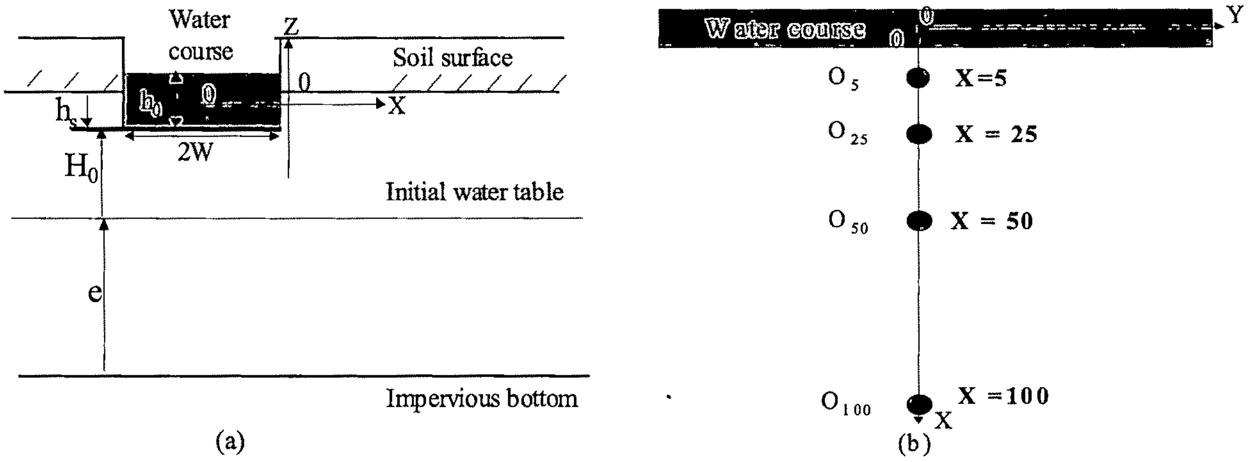

Fig. 1. Schematic diagram showing (a) watercourse positional parameters in horizontal X and vertical Z plane: water depth ho, width 2W, height of the bottom from water table Ho, height of the bottom from soil surface hs (b) observation wells position in horizontal X and watercourse length Y planes at indicated orthogonal distances

RESULTS AND DISCUSSION

Water table rise R and fall F increased with time at all orthogonal distances X = 5, 25, 50 and& 100 m (Figs. 2a and 3a) with $r^2 > 0.95$. Indeed the regression line almost passed through the origin (Figs. 2b and 3b) with a little intercept (Eqns 1-8, Table 2). It meant that the groundwater flowed in horizontal direction during seepage from the watercourse under shallow water table condition. The square root time law had been reported to govern unsaturated horizontal infiltration in capillary tube (Malik *et al.*, 1978) and in porous media (Malik *et al.*, 1978) after Darcy law. While observing groundwater recharge from seepage from an ephemeral river, Abdulrazzak and Seytoux, (1983) have reported that after establishing hydraulic connection in the soil column between saturated watercourse bed and initial water table, the infiltration rates (seepage rate) equaled recharge rate and it was a case of horizontal groundwater flow.

The straight line relationship between water table rise rate RR and fall rate FR; and the inverse square root of time $1/t^{1/2}$ (Eqns 9-16, Table 2) are shown in Fig. 4 for rise and in Fig. 5 for fall at an orthogonal distance X = 5 m. The r^2 values equals to 0.765 at X = 5 m; it verified the validity of Darcy law for recharge rates. However the

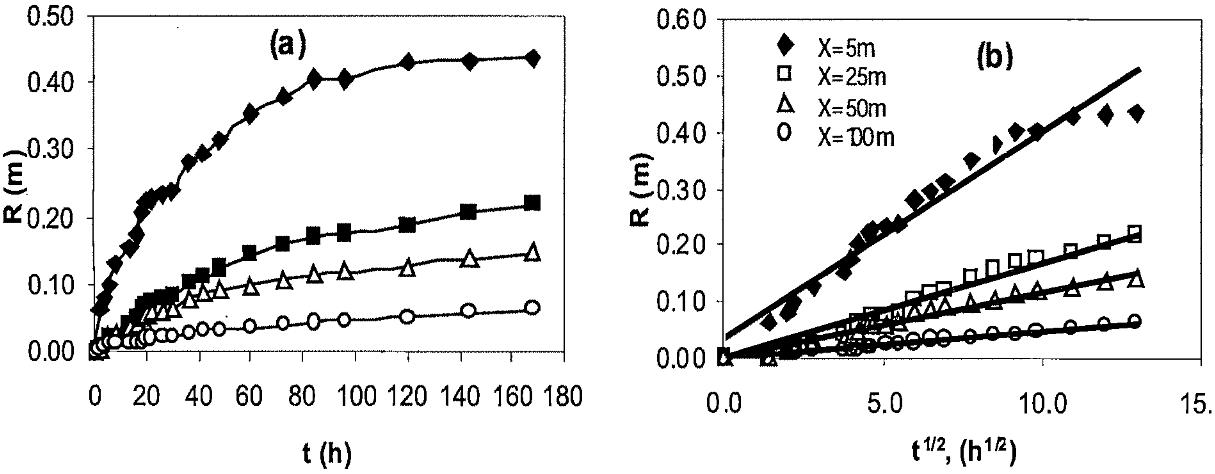

Fig. 2. Water table rise R at indicated distance X as a function of (a) time t and (b) square root of time $t^{1/2}$

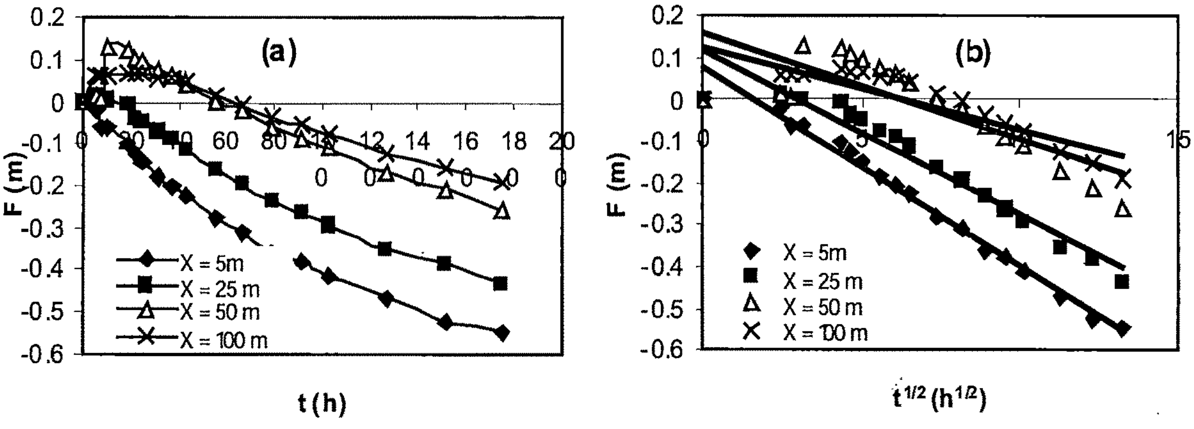

Fig. 3. Water table fall F at indicated distance X as a function of (a) time t and (b) square root of time $t^{1/2}$

Table 2. Relationship between rise and fall in water with time and orthogonal distance

Sr. No.	Water table rise/fall	Time (t)/ distance (X)	Registration equation	n	r^2
1	Rise (R) at 5 m	$t^{1/2}$, $(h^{1/2})$	$R=0.03661 \cdot t^{1/2} + 0.0351$	22	0.526*
2.	Rise (R) at 25 m	$t^{1/2}$, $(h^{1/2})$	$R=0.0169\ t^{1/2}$	22	0.961*
3.	Rise (R) at 50 m	$t^{1/2}$, $(h^{1/2})$	$R=0.0119\ t^{1/2}$	22	0.9771*
4.	Rise (R) at 100 m	$t^{1/2}$, $(h^{1/2})$	$R=0.0047\ t^{1/2}$	22	0.9728*
5.	Fall (F) at 5 m	$t^{1/2}$, $(h^{1/2})$	$F=-0.0474\ t^{1/2} + 0.0754$	18	0.9825*
6.	Fall (F) at 25 m	$t^{1/2'}$ $(h^{1/2})$	$F=-0.0393\ t^{1/2} + 0.1167$	18	0.9388*
7.	Fall (F) at 50 m	$t^{1/2'}$ $(h^{1/2})$	$F=-0.0255\ t^{1/2} + 0.158$	18	0.6554*
8.	Fall (F) at 100 m	$t^{1/2'}$ $(h^{1/2})$	$F=-0.0193\ t^{1/2} + 0.1252$	18	0.7153*
9.	Rise of rise (RR) at 5 m	$1/(t)^{1/2'}$ $(1/h^{1/2})$	$RR=0.06\ 1/t^{1/2} - 0.0031$	21	0.765*
10.	Rise of rise (RR) at 25 m	$1/(t)^{1/2'}$ $(1//h^{1/2})$	$RR=0.0088\ 1/t^{1/2} + 0.0043$	21	0.1068
11.	Rise of rise (RR) at 50 m	$1/(t)^{1/2'}$ $(1//h^{1/2})$	$RR=0.014\ 1/t^{1/2} + 0.0023$	21	0.2643
12.	Rise of rise (RR) at 100 m	$1/(t)^{1/2'}$ $(1//h^{1/2})$	$RR=0.0136\ 1/t^{1/2} + 0.0014$	21	0.2285
13.	Rate of fall (FF) at 5 m	$1/(t)^{1/2'}$ $(1//h^{1/2})$	$FF=0.0447\ 1/t^{1/2} - 0.0027$	17	0.7993*
14.	Rate of fall (FF) at 25 m	$1/(t)^{1/2'}$ $(1//h^{1/2})$	$RR=0.0063\ 1/t^{1/2} - 0.004$	17	0.1067
15.	Rate of fall (FF) at 50 m	$1/(t)^{1/2'}$ $(1//h^{1/2})$	$RR=0.0379\ 1/t^{1/2} - 0.0062$	17	0.1051
16.	Rate of fall (FF) at 100 m	$1/(t)^{1/2'}$ $(1//h^{1/2})$	$RR=0.0192\ 1/t^{1/2} - 0.0043$	17	0.7435*
17.	Rate (m)	X	$R=04092\ e^{-0.0192x}$	4	0.9683*
18.	RFall (m)	X	$F=0.5505\ e^{-0.0114X}$	4	0.9372*

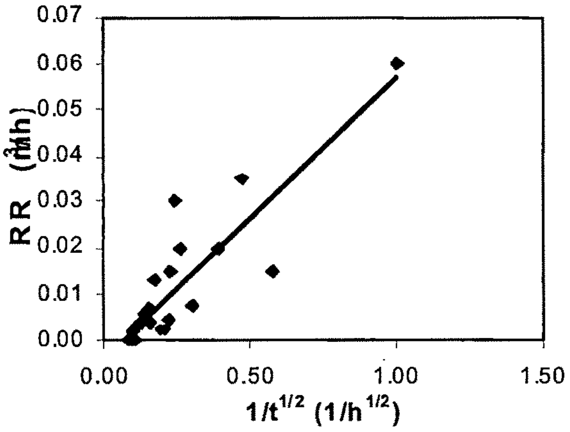

Fig. 4. Rise rate RR as a function of inverse square root time $1/t_{1/2}$ in observation well O_5

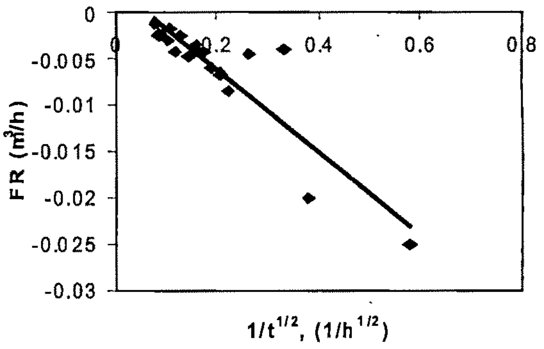

Fig. 5. Fall rate FR as a function of inverse square root time $1/t^{1/2}$ in observation well O_5

correlations were not found significant at large orthogonal distances X ≥ 25 m for the rise rate RR and fall rate FR. This might be due to error introduced in determining the RR and FR by central finite difference method and also due to slightly more time lag in reaching the waterfronts to X ≥ 25 m (Table 3).

Water table rise R at time t = 168 h and water table fall F at time t = 175 h were found exponentially related to orthogonal distances X (Fig. 6a and b). The regression equations are given in Table 2 with r^2 values more than 0.93. Such exponential relations between mound height R and distance X at any time t has also been reported by Abdulrazzak and Seytoux, (1983) for ephemeral river seepage, Phogat and Malik, (1997) for sand box canal and Phogat *et al.* (2000) for farm canal.

Water table rise R of 0.49m at X=5 m and 0.05 m at X=100 m in 168 hours (Table 3) implied that there was considerable seepage even from a lined water course under field conditions because some cracks developed in cement lined

Table 3. Water table rise R and fall F at indicated orthogonal distances X from watercourse at different times

	R (m) at X=					F (m) at X=			
Time (h)	5	25	50	100	Time (h)	5	25	50	100
2	0.064	0.004	0.0045	0.0021	6	-0.02	0.015	0.015	0.06
14	0.154	0.042	0.0347	0.0122	22	-0.125	-0.04	0.105	0.065
42	0.294	0.112	0.0861	0.0322	79	-0.36	-0.235	-0.06	-0.035
168	0.437	0.217	0.1374	0.0586	175	-0.55	-0.435	-0.26	-0.19

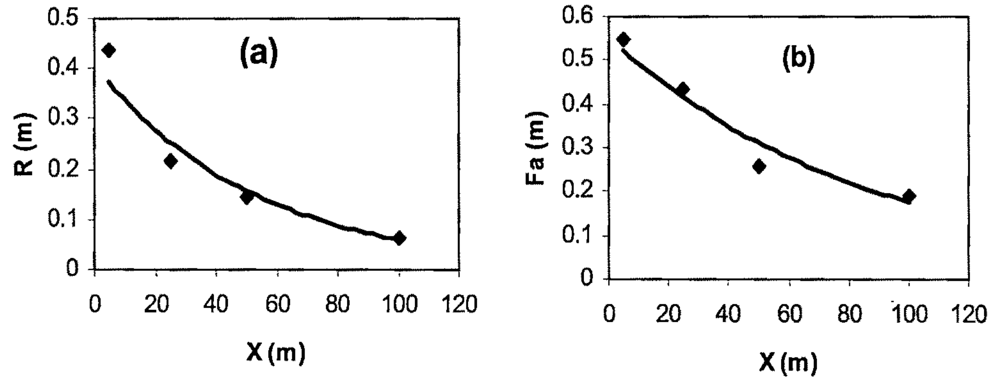

Fig. 6(a). Water table rise R and (b) absolute fall in water table Fa in observation wells as a function of distance X

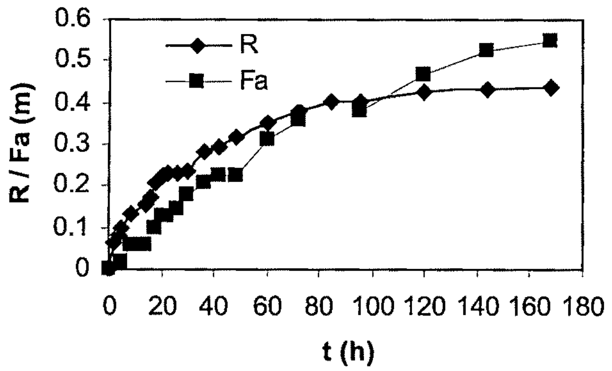

Fig. 7. Water table rise R and absolute fall Fa as a function of time t at X = 5 m

surfaces in due course of time and resulted in to preferential channel flow. The watercourse under study was 7 year old and such high seepage may take place. The practical implication of having considerable seepage from a 7 year old lined watercourse is that lining should be resorted only where absolutely necessary such as sandy beds with saline ground water and there should be more frequent and effective repairs of lined water courses. The seepage could be an effective and eco-friendly measure for groundwater recharge in falling water table situations.

Comparison of water table rise R with absolute fall Fa (Fig. 7) at X=5 showed that groundwater rise R was higher than groundwater fall up to 100 hours and then the order was reversed i.e. fall was larger than rise at time more than 100 hours.

It might be due to the fact that large time was taken by the advancing waterfront to reverse to receding waterfront. This time of crossing over increases as the distances increases and may be seen in Table 3.

CONCLUSION

- Water table rise R and fall F increased with time at all orthogonal distances X = 5, 25, 50 & 100 m with r2 > 0.95 and follows square root time law.
- Rise rate RR and fall rate FR of groundwater decreased with time following inverse square root law with r2 values more than 0.76 for X=5m.

- The groundwater rise R and fall F decreased with distance exponentially.
- Influencing orthogonal watercourse reach was 100 m in 168 hours leading to considerable seepage from the lined watercourse.

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Effect of organic matter and lime in remediation of heavy metals (Co, Ni & Pb) in Alfisols

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ABSTRACT

Soil samples differing in concentrations of heavy metals (Co, Ni and Pb) were categorized and five soil samples were taken under each categories *viz.*, high, medium and low. Farm yard manure as organic matter @ 10 t/ha and quantity of lime were applied on the basis of lime requirement to raise the pH 6.4. Five replication of 15 samples with 36 treatments under completely randomized design were taken. These soils were incubated in laboratory for 60 days (0, 20, 40 and 60 days). Results revealed that lime was effective in reducing the availability of Co and Pb than that of organic matter and combined application of 50% organic matter + 50% lime, while in case of Ni, lime was significantly superior to organic matter but at par with combined application of 50% organic matter + 50% lime. A significant reduction in their availability was also observed with increasing incubation periods.

Key words: Heavy metals, lime, organic matter.

In the rapid pace of development, we have inflicted serious damage to the natural resources and consequently we are now faced with the problems of clean water, healthy crop and refreshing air. The toxicity exerted by metals was realized as early as 4000 BC and Forbes in the year 1950 hinted towards arsenic toxicity faced by miners (Srivastava *et al.*, 2003). A high metal concentration in one soil may not result in an adverse effect, whereas a lower concentration in another soil may result in a greater effect. These heavy metals (Co, Ni and Pb) in plants cause chlorosis, necrosis, root tip damage, mitochondrial respiration and photosynthesis problem, impairing membrane permeability etc. while in human create cancerous and non-cancerous disorders. Reducing the mobility of heavy metal by means of a chemical additive (stabilization/solidification technique) was a much more cost effective solution for heavy metal contaminated soils (Dermatas, 1994). Stabilization/solidification can be accomplished through treatment with chemical additives. To safeguard the environment and the quality of natural resources for sustainability, present investigation was carried out to understand the effect of organic matter and lime in remediation of heavy metals (Co, Ni and Pb) in alfisols.

MATERIALS AND METHODS

The soil samples differing in heavy metals concentrations were categorized on the basis of DTPA-extractable content of cobalt, nickel and lead and five soil samples were taken under each categories *viz.*, high, medium and low. Available cobalt, nickel and lead were determined in DTPA extract of soils (Lindsay and Norvell, 1978). Concentration was fixed low, medium and high on the basis of observed values of DTPA-extractable Co, Ni and Pb. In case of cobalt low, medium and high concentration ranged from <1.5 , 1.5-2.5 and >2.5 mg/kg. Similarly for nickel, these concentrations ranges were <2 , 2-3 and >3 mg/kg, whereas for lead low, medium and high concentration range was fixed <1, 1-2 and >2 mg/kg concentration, respectively. FYM was applied @ 10t/ha and quantity of lime was applied on the basis of lime requirement to raise the pH 6.4. Lime requirement was determined by Shoemaker *et al.* (1961) buffer method. In combined application of organic matter and lime, the quantity of each was fixed to 50%. These soils were incubated in laboratory for 60 days (0, 20, 40 and 60 days) at normal temperature and its moisture was maintained at field capacity. Five replication of 15 samples with 36 treatments under completely randomized design were taken.

RESULTS AND DISCUSSION

Cobalt

The lowest availability of cobalt (0.43 mg/kg) was recorded under low concentration category of soil as compared to other two category of soil (Table 1). Of the materials used, lime was significantly superior to organic matter and combined application of 50% organic matter + 50% lime, in reducing the availability of cobalt. Among different incubation periods, the concentration of available cobalt decreased with the increase in incubation periods.

Interaction between soil group and material used, soil group and incubation period and used material vs incubation period on available cobalt were found statistically significant. High concentration soil group had weaker effect with organic matter, whereas low concentration soil group recorded strong effect with lime application which was at par with the combined application of 50% organic matter + 50% lime (Table 2). Similar results were reported by Backes *et al.* (1995).

Under low concentration soil group, 60 days of incubation period were significantly superior to 20 days but at par to 40 days (Table 3). Application of lime remained at par with combined application of 50% organic matter + 50% lime, when incubated for 60 days. However, lime was superior to the other treatments for reduction of cobalt concentration (Table 2).

Further, cobalt availability decreased with increasing the incubation period. However, fast response in reducing the cobalt availability was

Table 1. Effect of different amendments and incubation period on Co, Ni and Pb availability in different soil groups

	DTPA- extractable (mg/kg)		
	Co	Ni	Pb
Soil group (concentration)			
High	1.40	2.42	1.77
Medium	0.85	1.35	1.08
Low	0.43	1.05	0.49
SEm(±)	0.03	0.05	0.06
C.D. (P=0.05)	0.08	0.14	0.15
Materials used			
Organic matter	1.09	1.73	1.20
Lime	0.67	1.51	0.99
50% organic matter + 50% lime	0.91	1.59	1.15
SEm(±)	0.03	0.05	0.06
C.D. (P=0.05)	0.08	0.14	0.15
Incubation period (days)			
00	1.77	2.57	1.67
20	1.03	1.71	1.25
40	0.47	1.26	0.90
60	0.28	0.89	0.63
SEm(±)	0.032	0.059	0.063
C.D. (P=0.05)	0.089	0.163	0.176

Table 2. Interaction effect between different material with period of incubation and different soil group on cobalt availability (mg/kg)

	Incubation periods (days)				Soil groups		
	00	20	40	60	High	Medium	Low
Organic	1.78	1.43	0.73	0.43	1.77	1.00	0.50
Lime	1.78	0.53	0.25	0.13	1.01	0.67	0.34
50% Organic + 50% lime	1.78	1.14	0.44	0.29	1.43	0.87	0.86
SEm(±)			0.055			0.048	
C.D. (P=0.05)			0.155			0.134	

noted at 20 days of incubation with lime, respectively (Table 4). Strawn and Sparks (2000) reported that increasing in incubation time resulted in an increase of adsorption. Similar observations were reported by Benjamin and Leckie (1981) and Shao *et al.* (1993).

Nickel

A perusal of data (Table 1) showed that the lowest availability of nickel (1.05 mg/kg) was recorded under low concentration soil group as compared to other soil groups. Lime was significantly superior to organic matter while at par with combined application of 50% organic matter + 50% lime in reducing the availability of nickel and the concentration of available nickel decreased with the increase in incubation periods. The lowest concentration of available nickel was recorded under 60 days of incubation (0.89 mg/kg). Similar findings were observed by Schultz *et al.* (1987).

Interaction between soil group and incubation periods on nickel availability was found statistically significant and indicated that low concentration soil group was at par with medium concentration soil group under 60 days of incubation periods. Interaction between soil group and material used as well as material used and incubation periods was non-significant (Table 3).

Impact of different amendments on DTPA-extractable nickel (Table 4) show that maximum change was observed in low concentration soil group with lime *i.e.*, 78.78% at 60 days of incubation periods. Shao *et al.* (1993) reported that extractable Co and Ni showed significantly negative correlations with $CaCO_3$ content. Carbonate bound Co and Ni were highly significantly positively correlated with soil pH and $CaCO_3$ content. In studies of Ni adsorption-desorption in the soil, Pombo *et al.* (1989) observed that liming-induced higher soil pH increased soil adsorption capacity. Similar results were also observed by Martin *et al.* (2003) and Bingham *et al.* (1979).

Lead

Minimum availability of lead (0.49 mg/kg) was observed under low concentration soil group as compared to other soil groups (Table 1). In reducing the availability of lead, lime was significantly superior to organic matter and combined application of 50% organic matter + 50% lime. Among different incubation periods, the concentration of available cobalt decreased with the increase in incubation periods. The lowest concentration of available lead was recorded under 60 days of incubation (0.63 mg /kg). Kuo and Mikkelsen (1980); Strawm and Sparks (2000) also reported similar results.

Interaction between soil groups and incubation periods on lead availability was found statistically significant (Table 3) and showed that 40 days remained at par with 60 days under low concentration soil group. Interaction between soil group and material used as well as material used and incubation period was not observed significant.

When soils were treated with organic matter, lime and combination of 50% organic

Table 3. Interaction effect of different soil groups with period of incubation on heavy metal availability (mg/kg)

	Cobalt				Nickel				Lead			
Soil group	00	20	40	60	00	20	40	60	00	20	40	60
High	2.78	1.59	0.78	0.46	3.74	2.51	1.87	1.56	2.58	1.98	1.43	1.07
Medium	1.69	1.03	0.41	0.25	2.32	1.44	1.02	0.65	1.61	1.22	0.89	0.57
Low	0.86	0.47	0.23	0.13	1.64	1.18	0.90	0.48	0.84	0.54	0.37	0.24
SEm(±)		0.05				0.10				0.10		
C.D..(P=0.05)		0.15				0.28				0.53		

Table 4. Effect of amendments and different soil groups on availability of heavy metals (mg/kg)

			Organic matter			Lime			50% organic matter + 50% lime		
	Days/ Soil group	Initial days	20 days	40 days	60 days	20 days	40 days	60 days	20 days	40 days	60 days
Cobalt	High	2.78	2.17	1.36	0.77	0.71	0.34	0.19	1.89	0.62	0.44
	Medium	1.69	1.48	0.51	0.33	0.56	0.28	0.15	0.85	0.45	0.28
	Low	0.86	0.63	0.33	0.19	0.31	0.13	0.06	0.48	0.24	0.14
Nickel	High	3.74	2.78	2.08	1.69	2.32	1.69	1.44	2.44	1.83	1.56
	Medium	2.32	1.64	1.13	0.72	1.28	0.93	0.58	1.39	0.99	0.67
	Low	1.64	1.34	1.03	0.58	1.04	0.82	0.35	1.15	0.86	0.50
Lead	High	2.58	2.22	1.52	1.17	1.72	1.22	1.00	2.02	1.55	1.15
	Medium	1.61	1.38	1.08	0.70	0.98	0.62	0.44	1.29	0.99	0.58
	Low	0.84	0.65	0.47	0.32	0.40	0.25	0.16	0.56	0.40	0.25

matter + 50% lime in low concentrated soil group, the initial concentration reduced from 0.84 mg/kg to 0.32, 0.16 and 0.25 mg/kg, respectively at 60 days of incubation (Table 4). Overall, maximum changes were occurred with lime in low concentration soil group (81.3%) at 60 days of incubation periods. Chaudhuri *et al.* (2003) observed an increase in pH of the amended soil restricted the metal mobility in their labile forms and was more pronounced after liming the treatments. Lime addition to the treatments further reduced the transfer and accumulation of metals from the soil to the plant, even though the relationship remained linear. Similar observations were reported by Alpaslan and Yukselen (2002) and Alloway (1990).

CONCLUSION

Lime was found to be effective in reducing the availability of Co and Pb than that of organic matter and combined application of 50% organic matter + 50% lime while in case of Ni, lime was significantly superior to organic matter but at par with combined application of 50% organic matter + 50% lime. With increasing incubation periods, their availability also reduced significantly.

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Evaluation of marketing channel options for guava in Kota district of Rajasthan

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ABSTRACT

Guava (*Psidium guajava* L.) is one of the most important commercial fruit crops in India. The present study explores price spread for guava through different marketing channels. The multi-stage sampling procedure was followed to collect primary data from 200 farmers and traders during 2005-06. Therefore, different marketing channels (local and distant) were identified in marketing of guava. The large share of the produce was sold through pre- harvest contractor to distant terminal market. The net share of wholesalers was highest in channel-III. The analysis of price spread revealed that price spread was lowest in channel-III. Therefore, channel-III was the most remunerative channel for farmers in local markets The study suggested that there should be agro-processing industries in the district, sound market intelligence system so that information regarding price prevailing in different local and distant markets can be made available to farmers.

Key words : Marketing channel, guava, kota, price spread.

Guava (*Psidium guajava* L.) is one of the most important commercial fruit crops in India. It belongs to Myreteaceae family. It claims to the fourth most important fruit in area and production after mango, banana and citrus in the country. It is now widely grown all over the tropics and sub-tropics climate. Guava is rich source of vitamin C and pectin. Its nutritional value is comparable to apple, so it is known as the apple of tropics. It covers an area of 0.15 million hectares with a production of about 1.80 million tonnes in the country (Vital Horticulture Statistics, 2002-03). It is grown extensively in Uttar Pradesh, Bihar, Madhya Pradesh, Maharashtra, Andhra Pradesh, Tamil Nadu and Karnataka states.

The state of Rajasthan is considered to be the potential area for fruits growing. The climatic conditions of state are also suitable for cultivation of guava fruit. In Rajasthan, guava occupies 1988 hectares area under cultivation in 2003-04 and Kota district is well known for its production and productivity. Kota district occupied 206 hectares of area and 11268 metric tonnes production under guava cultivation in the year 2003-04 (Vital Statistics of Horticulture, 2004-05). The two commercially important varieties of guava grown in Rajsthan are "Allahabad Safeda" and "Lucknow-49". The other important varieties are Banarsi, Hafis, Allahabad Surkha, and Sindh etc. Marketing aspect of guava is not less important. Marketing is regarded as an important multiplier and effective engine of development. Due to inefficient marketing system, the farmer's share in consumer rupee is very low. A significant share of consumer rupee is cornered by intermediaries (Khushk *et al.*, 1999). An efficient system of marketing of guava will result in reduction of marketing cost and middlemen's profit, thereby, increasing farmer's share in consumer rupee.

An attempt was made to explore pattern of production and price spread for guava through different marketing channels in Kota district of Rajasthan. The specific objectives are to study different local and distant marketing channels, marketing costs and price spread in marketing of guava; to study constraints faced by farmers and traders in marketing and suggest measures to improve marketing of guava.

MATERIALS AND METHODS

Selection of study area

The farmers' and traders' survey was conducted to examine the marketing costs in different channels during 2005-06. For the present study, Kota district of Rajasthan was purposely selected as it ranked first on area (203 ha) and production (8934 metric tonne) of guava in the state during TE 1999 to 2001. Two tehsil *viz.* Ladpura and Ramganj Mandi were selected on the basis of highest area and production. Both in terms of area and production Ladpura and stood first and Ramganj Mandi stood second. From selected tehsil two markets (one large and another small) were selected on the basis of arrival of guava to the market. The large market with highest arrival of guava was selected from Ladpura tehsil and the small market having low arrival of guava was selected from Ramganj Mandi. Villages belonging to the selected markets were listed along with area under Guava in each village. On the basis of largest area under guava, 13 villages, six from Ladpura tehsil and seven from Ramganj Mandi were selected. From the selected villages, complete lists of Guava orchards along with area under guava were taken. These orchards were pooled and arranged in ascending order based on area under guava. The cumulative total sampling method was used in order to divide them into three size groups i.e. small, medium and large size groups. The orchardists from the top of the list accounting for one-third of the total cultivated area under guava were termed as small orchardists. The orchardists from the middle of the list accounting for next one-third of total area were termed as the medium orchardists and the orchardists from the bottom of the list accounting for remaining one-third of the total area under guava were termed as the large orchardists. The sample of 40 farmers was drawn randomly from each selected villages. Total land holding size under guava of sample farmers was 76.4 hectares in selected tehsils. Investigation regarding different marketing channels was done by selecting a random sample of such intermediaries as 40 pre-harvest contractor, 40 wholesalers, 40 commission agents and 40 retailers. These were selected randomly for study.

Analytical framework

Price spread: To study the price spread in marketing of guava, the marketing costs and margins were worked out as under:

Marketing cost and marketing margins: Total cost of marketing was calculated as under

$$C = Cr + \sum_{i=1}^{n} Cmi$$

where, C = Total cost of marketing, Cr = Cost borne by the producer farmer from the time at which the produce leaves the farm till the sale of the produce and Cmi = Cost incurred by the ith middlemen in the process of buying and selling.

Absolute margin = $P_{Ri} - (P_{pi} + C_{mi})$

where, P_{Ri} = Total value of receipts (sale price),

$$\text{Relative Margin} = \frac{P_{Ri} - (P_{pI} + C_{mi})}{P_{pi}} 100$$

P_{pi} = Total purchase value of goods (purchase price), and C_{mi} = Costs incurred in marketing

The producer share in consumer rupee was worked out as under:

where, P_s = Producer's share in consumer rupee, P_F = Price of the produce received by the farmer;

$$P_s = \frac{P_l}{P_c} \times 100$$

and P_c = Price of the produce paid by the consumer.

RESULTS AND DISCUSSION

The results for the magnitude of costs incurred in marketing and margins earned by market intermediaries in the process of movement of guava from producer to consumer through different channels have been compared for different channels. Price spread and producer's share in consumer's rupee have also been discussed.

Scenario of fruit crops in Kota district

The comparative analysis of area and production of different fruit crops in Kota district was shown in the Table 1. The perusal of the table revealed that Kota had accounted 10.45% area of total guava area and due to good productivity, it contributed 26.45% share in total production of Guava in the State. Mango was the other important fruit crop in the district which covered 4.22% area and 7.52% production of total mango production in State. Lemon was also important fruit crop in the sense that it accounted for 2.28% area and 20.25% production of total lemon area and production in the state.

Marketing channels and price spread

The study was undertaken to analyse the marketing channels adopted for the marketing of guava in Kota district. Three marketing channels were identified for local market and one for distant market. The marketing costs of different marketing channels were presented in Table 2.

Channel-I: Producer→Pre-Harvest→Contractor Commission Agent→Wholesaler→Retailer Consumer.

The marketing cost of channel-I indicated that the cost incurred by pre-harvest contractor was Rs.112.78 per quintal of guava which was 9.91 per cent in consumer rupee. Cost incurred by wholesaler was ₹ 193.57 per quintal which was 17.01% in consumer rupee. Cost incurred by Retailer was ₹ 15 per quintal which was 1.32%in consumer rupee. Transportation was major cost item for all the middlemen. Other major costs incurred by the pre-harvest contractor were on packaging, picking and grading while other major expenses for wholesaler were commission to agent, mandi taxes and quantity losses during the purchase. In this channel, price received by the producer was ₹ 263.81 per quintal, which was only 23% in consumer's rupee.

Channel-II: Producer→Commission Agent →Wholesaler→Retailer Consumer.

Marketing costs incurred in channel-II presented that the cost incurred by producer was Rs 173.90 per quintal which was 16.03% in consumer's rupee and cost incurred by

Table 1. Status of Kota district in fruit crops in Rajasthan (2001-02)

Fruits crops	Area (ha)		Production (MT)	
	Kota	Rajasthan	Kota	Rajasthan
Mango	274 (4.22)	6493	7405 (7.52)	98493
Guava	197 (10.45)	1885	5982 (26.45)	22612
Orange	106 (2.08)	5101	1819 (5.31)	34255
Lemon	65 (2.28)	2845	3686 (20.25)	18206
Mausmi	7 (1.26)	554	49 (6.71)	730
Ber	6 (0.82)	736	115 (2.47)	4661
Papaya	4 (1.07)	374	110 (3.24)	3394
Pomegranate	1 (0.26)	382	5 (0.49)	1008
Aonla	1 (0.25)	396	6 (0.27)	2219
Other Fruits	29 (4.52)	641	600 (3.96)	15146
Total	690	21948	19777	200724

Source: Vital Horticulture Statistics, 2002-03

Note: Figures in parentheses show per cent share of Kota district in Rajasthan

Table 2. Different marketing channels costs and margins

Particulars	Channel-I	Channel-II	Channel-III	Channel-IV*
	₹/q	₹/q	₹/q	₹/q
Net price received by producer	263.81(23.19)	366.03 (33.74)	488.92 (56.96)	286.44 (20.06)
Cost incurred by pre-harvest contractor/Producer	-	-	-	-
Transportation	51.99 (4.57)	47.99 (4.42)	47.06 (5.49)	324.30 (22.72)
Other costs (watch &ward, picking, grading, packing empty boxes and loading)	60.79 (5.35)	125.91 (11.61)	135 (15.73)	145.96 (10.22)
Total cost	112.78 (9.91)	173.90 (16.03)	182.06 (21.22)	470.26 (32.94)
Net margin of Pre-harvest contractor	238.50 (20.96)			128.18 (8.98)
Sale price of pre-harvest contractor/Producer	615.09 (54.06)	539.93 (49.77)	670.98 (78.18)	884.88 (61.98)
Cost incurred by wholesaler	-	-	-	-
Transportation cost	17.63 (1.55)	6.31 (0.58)		25.12 (1.76)
Other costs {mandi taxes (1.6%), commission agent (6%), weighing, grading, empty baskets, loading, unloading and room rent}	175.94 (15.46)	175.41 (16.17)		186.00 (13.03)
Total cost	193.57 (17.01)	186.72 (17.21)		211.12 (14.79)
Net margin of wholesaler	92.80 (8.16)	95.36 (8.79)		152.86 (10.71)
Sale price of Wholesaler	901.46 (79.23)	822.01 (75.77)		1248.86 (87.48)
Cost incurred by retailer	-	-	-	-
Mandi taxes (1.6%) and commission agent (6%)			64.47 (7.51)	
Transportation cost & labour cost and other cost	15.00 (1.32)	16 (1.47)	16.80 (1.96)	12.54 (0.88)
Total cost	15.00 (1.32)	16 (1.47)	81.27 (9.47)	12.54 (0.88)
Net margin of retailer	221.31 (19.45)	246.88 (22.76)	106.04 (12.35)	166.19 (11.64)
Consumer's purchase price	1137.77 (100.00)	1084.89 (100.00)	858.29 (100.00)	1427.59 (100.00)

Figures in parenthesis are Percent Share in Consumer's Rupees
*Distant Marketing Channel

Table 3. Relative share and marketing cost of producer and pre-harvest contractor per quintal of guava (₹/q)

Channel	Price paid by consumer	Sale price of grower	Marketing cost	Net share of growers	Purchase price of pre-harvest contractor	Sale price of pre- harvest contractor	Marketing cost of pre- harvest contractor	Net share of pre- harvest contractor
Channel-I	1137.77	263.81	-	263.81	263.81	615.09	112.78	238.5
Channel-II	1084.89	539.93	173.90	366.03	-	-	-	
Channel-III	858.29	670.98	182.06	488.92	-	-	-	
Channel-IV*	1427.59	286.44	-	286.44	286.44	884.88	470.26	128.18

*Distant marketing channel

Table 4. Relative share and marketing cost of wholesaler and retailer in guava marketing (₹/q)

Channel	Price paid by consumer	Sale price of grower	Marketing cost	Net share of growers	Purchase price of pre-harvest contractor	Sale price of pre- harvest contractor	Marketing cost of pre- harvest contractor	Net share of pre- harvest contractor
Channel-I	1137.77	615.09	901.46	193.57	92.8	901.4	15	221.31
Channel-II	1084.89	539.93	822.01	186.72	95.36	822.0	16	246.88
Channel-III	858.29	-	-	-	-	670.98	81.27	106.04
Channel-IV*	1427.59	884.88	1248.86	211.12	145.86	1248.86	12.52	166.19

*Distant marketing channel

Table 5. Problems faced by farmers and traders in marketing of guava

S. No.	Problems faced by farmers	Small	Medium	Large	Per cent of total farmers and traders faced problems
1.	Low price of guava	20	7	3	75
2.	Lack of cooperative marketing system in village	15	6	5	62.5
3.	Problems of transportation	7	6	5	45
	Problems faced by traders				
1.	Lack of storage				75
2.	Lack of processing industries				65
3.	High cost of transportation in distant markets				35

Table 6. Price spread in different marketing channels

Particulars	Channel-I		Channel-II		Channel-III		Channel-IV	
	₹/q	Percent share in consumer's rupee	₹/q	Percent share in consumer's rupee	₹/q	Percent share in consumer's rupee	₹/q	Percent share in consumer's rupee
Producer's net price	263.81	23.19	366.03	33.74	488.92	56.96	286.44	20.06
Cost incurred by								
(a) Producer	-	-	173.90	16.03	182.06	21.22	-	-
(b) Pre-harvest contractor	112.78	9.91	-	-	-	-	470.36	32.94
(c) Wholesaler	193.57	17.01	186.72	17.21	-	-	211.12	14.79
(d) Retailer	15	1.32	16.00	1.47	81.27	9.47	12.54	0.88
Total cost	321.35	28.24	376.62	34.71	263.33	30.69	693.92	48.61
Margin of middlemen								
(b) Pre-harvest contractor	238.50	20.96	-	-	-	-	128.18	8.98
(c) Wholesaler	92.80	8.16	95.36	8.79	-	-	152.86	10.71
(d) Retailer	221.31	19.45	246.88	22.76	106.04	12.35	166.19	11.64
Total margin	552.61	48.57	342.24	31.55	106.04	12.35	447.23	31.33
Consumer purchase price/ Retailer sale price	1137.77	100.00	1084.89	100.00	858.29	100.00	1427.6	100.00

wholesaler was Rs 186.72 per quintal which was 17.21 per cent in consumer's rupee. Cost incurred by retailer was only 1.47 per cent of consumer's rupee. Cost of boxes and baskets for packaging was the major part of marketing cost for producer as well as for wholesaler i.e., ₹ 78.16 and ₹ 8.55 per quintal. Transportation was the other major cost item for producer which accounted for ₹ 47.99 per quintal. Picking and grading were also important cost items of marketing cost for producer. In this channel, price received by the producer was ₹ 366.03 per quintal, which was 33.74 per cent in consumers rupee.

Channel III: Producer→ Commission Agent Retailer→ Consumer.

Marketing costs incurred by different intermediaries in channel-III presented that the total cost incurred by producer was ₹ 182.06 per quintal that was 21.22 per cent in consumer's rupee and the cost incurred by retailer was ₹ 81.27 per quintal which was 9.47 per cent in the consumer's rupee. Cost incurred by producer was mainly on packaging material, transportation, picking and grading. Mandi tax and payment to commission agent was major cost items for retailer here. In this channel, price received by the producer was ₹ 488.92 per quintal which was 56.97 per cent in consumers rupee.

Channel IV (Distant Market): Producer→ Pre-harvest Contractor→ Commission Agent Wholesaler→ Retailer→ Consumer.

Pre-harvest contractor of mainly transported the study area, their produce to the distant markets to the place like Neemach, Indore, Udaipur and Chittorgarh because they received remunerative prices. The Guava produce was transported to distant markets mainly by pre harvest contractor. It was not possible for the researcher to visit distant markets of Neemach, Udaipur and Chittorgarh due to paucity of time and money therefore, approximate cost incurred by wholesalers and retailers in the distant markets were obtained from farmer and pre harvest contractors who sold their produce in distant market.

The analysis of marketing cost of channel IV showed that total cost incurred by pre harvest contractor in distant market was ₹ 470.276 per quintal which was 32.94 per cent in consumer's rupee. The cost incurred by wholesaler was ₹ 211.12 per quintal which was 14.79 per cent in consumer rupee and cost incurred by retailer was ₹ 12.54 per quintal which was 0.88 per cent in consumer's rupee. The cost incurred on transportation by the pre-harvest contractor was very high in this channel i.e., ₹ 324.30 per quintal. Cost incurred on packaging was also higher than in other channels of the local market. Producer received ₹ 286.44 per quintal which was only 20.06 per cent in consumer's rupee. Purchase price of consumer was ₹ 1427.59 per quintal of guava.

Relative share of producer, pre-harvest contractor, wholesaler and retailer in consumer rupee in different marketing channels.

The analysis of relative share of producer and pre-harvest contractor per quintal of guava presented in Table 3. It revealed from this table that the channel III was most remunerative for the orchardists in local market because it ensured highest net share of grower in consumer's rupee and have least number of intermediaries. This channel provided highest net share for producer 56.96 per cent of consumer's rupee. The share of producer was 33.74 per cent in channel II in which price paid to producer was ₹ 366.03/q. Channel I and channel IV, both having maximum intermediaries, ensured very less share to the producer i.e., 23.19 and 20.06 per cent, respectively. Price paid by consumers was also higher in these channels.

The pre-harvest contractor had 20.96 per cent share in consumer's rupee when guava was sold in local market which decreased to 8.98 per cent only when the produce was sold to distant market. In absolute terms also, net margin of pre-harvest contractor was lesser in channel IV (₹ 128.18/q) as compared to channel I (₹ 238.5/q). Price paid by consumer in channel IV was very high due to more transportation cost. The relative share of wholesaler and retailer in consumer's rupee is shown in Table 4 it revealed from this table that the net share of wholesaler was maximum in channel IV in which guava was sold to distant market followed by channel-II and channel-I. Even after maximum cost requirement for wholesaler in distant marketing channel, it ensured ₹ 145.86 per quintal of guava to the wholesaler, which was 10.22 per cent of consumer's rupee. In local market it was highest (8.79 per cent) in channel II followed by channel I (8.16%).

There local market channel II ensured highest per cent share of retailer in consumer's rupee (22.76 per cent) yielding a net margin of ₹ 246.88 per quintal of Guava and net margin of ₹ 221.31 per quintal of Guava to the retailer but channel-III, in which retailer directly purchased from the producer and sold produce to the consumer directly, gave the retailer least net margin. In the distant market also, per quintal of guava, retailer could earn net margin of only ₹ 166.19.

Price spread in different marketing channels

Price spread in channel I is presented in table: 6, the table showed that the producer's share in consumer's rupee was 23.19 per cent and price spread was as high as 76.81 per cent, out of which 28.24 per cent was accounted for marketing costs and 48.57 per cent accounted for by margins. The analysis of price spread in channel II showed that the producer's share in consumer's rupee was 33.74 per cent and price spread was 66.26 per cent, out of which, 34.71 per cent was accounted for marketing costs and 31.55 per cent was accounted for by margins of wholesaler and retailers. The producer's share in consumer's rupee in channel III indicated that there was 56.96 per cent and price spread was lowest in this channel (43.03 per cent). Out of the total spread of 43.03 per cent, total cost was 30.69 per cent and the margin was 12.35 per cent only. In case of distant marketing channel the share of producer in consumer's rupee was ₹ 286.44 which was 20.06 per cent of consumer's rupee. The price spread was 79.45 per cent out of which 48.61 per cent was accounted for by the marketing cost and 31.33 per cent were accounted for by margin of pre harvest contractor, wholesaler and retailer. On the whole, maximum cost incurred on marketing of guava was maximum in channel IV i.e., ₹ 693.93 per quintal of guava while, margins earned were maximum in channel I i.e., ₹ 552.61 per quintal of guava.

Constraints faced by farmers and traders in marketing of guava and suggestions for this improvement

To study the problems faced by farmers and traders in marketing of guava survey were conducted. Based on that data; the suggestions were made for the improvement of marketing of guava in Kota district. There were more number of marketing channels in which farmers and traders are not free from constraints in marketing of guava. The constraints faced by farmers and traders in marketing of guava are presented in Table 5 which indicated that 75 per cent of farmers faced problem of low price of guava, 62.5 per cent farmers felt lack of cooperative marketing in village and 45 per cent producers faced problem in transportation. Problem of low price was felt maximum by the small farmers i.e., 83.33 per cent while problem of lack of cooperative marketing and problem of transportation was a problem for 100 per cent large farmers. The survey of traders about problems faced by them in trading of guava indicated that 75 per cent of traders had problem of storage and 65 per cent felt that there should be processing industry in the study area. There 35 per cent traders told that transportation costs for distant market was higher which reducing their net margin.

Suggestion for improvements in marketing of guava

I. Farmers do not get proper market price information. Therefore, there is a need to establish sound market intelligence system by the government so that the farmers can sell their produce in those markets where prices are favorable.
II. Farmers should be educated and promoted for co-operative marketing so that they can take advantage of higher prices in distant market at lower cost of marketing, using collective storage and transportation facilities.
III. There should be provided cheap transportation facilities to those traders/ farmers selling their produce in distant markets. Government should announce concessional freight rates during post harvest period.
IV. There are no agro-processing industries (like NAFED). Therefore, there is need to establish processing industries where traders/farmers can sell produce conveniently. This will push up their income

considerably without incurring heavy costs on transportation of their produce to distant markets.

V. Government can help farmers for storage facilities either by providing government cold storage or by farmers for providing subsidy on cold storage.

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National Seminar on Indian Agriculture: Preparedness for Climate Change

24-25 March, 2012

RECOMMENDATIONS

Agriculture in India is crucial for ensuring food and livelihood security of the country. It engages almost two-third of the workforce in gainful employment and accounts for a significant share of India's Gross Domestic Product. Several industries depend on agricultural production for their requirement of raw materials. On account of its close linkages with other economic sectors, agricultural growth has a multiplier effect on the entire economy of the country.

Indian agriculture, with 2/3rd rainfed area, is exposed to potential risks arising from climate variability and climate change induced stresses. Natural calamities such as drought and flood occur frequently in many parts. These risks coupled with the existing vulnerabilities such as poverty, high population density, depletion of important natural resources, shrinking cultivable land, and insufficient rural infrastructure are expected to exacerbate the stress on Indian agriculture through a range of direct and indirect impacts. Since most of the agricultural production takes place in rural heartlands by engaging people from the marginalized sections of the society, the coping capacity of the farmers during climatic extremities are limited. Moreover, constraint in accessing institutional or formal financial mechanisms for agricultural credit is another significant factor that contributes to high vulnerability of the sector. Similarly, agricultural markets and food supply chains in India are mainly in the unorganized sector. Post-harvest losses due to inadequate storage and transport infrastructure, lack of market information and intelligence reduce the profitability of farming systems.

Vulnerability of India in the event of climate change is more pronounced due to its ever increasing dependency on agriculture, excessive pressure on natural resources and poor coping mechanisms. Thus, the combination of high vulnerability and low adaptive capacity makes enhancing resilience in Indian agriculture and allied sectors a challenging task. However, while on one hand, agriculture sector is likely to get affected due to climate change, on the other hand, the sector can also join hands with other sectors in controlling emission of greenhouse gases (GHGs). It is therefore, pertinent to develop technologies to reduce emission of GHGs from agriculture. This will not only mitigate climate change but also reduce consumption of costly inputs by enhancing their use efficiency and increase farmers' income by producing more with less of inputs.

Indian Society of Agricultural Science, New Delhi was established in the year 1979 under the patronage of Dr. M.S. Swaminathan with the objective of serving as an umbrella society covering all the disciplines related to agriculture. The Society organized a National Seminar on Indian Agriculture: Preparedness for Climate Change during 24-25 March, 2012. The recommendations emerged out in the Seminar are given below.

1. For ensuring country's food security both in the short and long term and making agriculture sustainable and climate-resilient, appropriate adaptation and mitigation strategies have to be developed.
2. Although Indian farmers have evolved many coping mechanisms over the years, these have fallen short of an effective response

strategy in dealing with recurrent and intense forms of extreme events on the one hand and gradual changes in climate parameters including rise in surface temperatures, changes in rainfall patterns, increase in evapo-transpiration rates and degrading soil moisture conditions on the other. The need of the hour is, therefore, to synergise modern agriculture research with the indigenous wisdom of the farmers to enhance the resilience of Indian agriculture to climate change. To start with traditional knowledge bases should be documented and validated.

3. To cope up with the negative impacts of climate change and climatic variability the focus should be [on adaptation] to help small and marginal farmers of developing countries for sustainable livelihood security. By developing comprehensive and integrated strategy and transferring appropriate technologies for climate-resilient agriculture.

4. Efforts should be intensified to develop stress tolerant varieties suitable for different agro-climatic zones. Tools of new sciences, microbial genetics, terrestrial and marine genetic resources should be exploited to develop designer crops for climatic stress tolerance. There is a need to revisit the regulatory mechanism related to genetically modified crops, particularly in the context of changing climate.

5. There is large gap between potential and actual yields obtained by farmers. This gap must be bridged by enhancing input use and their use-efficiency.

6. Integrated farming system, conservation agriculture, agro-forestry, organic farming practices and watershed development programmes should be promoted on large scale to enhance livelihood security and income of farmers.

7. Basic research in C and N dynamics, conservation agriculture and simulation modeling should be carried out to enhance our understanding of climate change impact, mitigation and adaptation. Impact assessment studies using simulation models and modern facilities such as FACE (Free Air Carbon Dioxide Enrichment), [redacted] Carbon Dioxide and Tempe Enrichment), phenomics, controlled environment chambers should be developed in the lead research institutes.

8. Potential of carbon sequestration in different soils and crop management conditions should be estimated and efforts should be made for providing benefit of C sequestration to small farmers through carbon trading.

9. Water availability will be a major constraint in the climatic change scenarios. Development and dissemination of technologies for enhancing water use efficiency, early warning systems and management of drought and flood should be given priority.

10. Horticulture production may be affected by climate change. Germplasms of potential root stock and scion materials should be developed against biotic and abiotic stresses. Production technologies for future fruit+vegetable crops should be developed and disseminated.

11. Livestock sector is a major source of GHGs and are vulnerable to climate change. Systematic studies should be carried out for updating the GHG emission inventory from Indian livestock and develop adaptation and mitigation measures. Emphasis should be given to those animals such as camel and yak, which are especially threatened because of climate change.

12. Occurrence of new pest and diseases should be monitored and suitable control measures be developed and scaled up. Pest risk analysis with respect to climate variability and climate change should be done regularly.

13. Climate analogues should be identified and impacts of different climatic conditions should be assessed.

14. Data sharing among various organizations should be streamlined. A campaign like 'one rain gauge for one village' should be implemented. National risk fund and micro-financing should be developed for climate risk management.

15. Adaptation and mitigation technologies should be made part of MNREGA (Mahatma Gandhi National Rural Employment Act) and ATMA (Agricultural Technology Management Agency) projects.

16. Capacity building and awareness on multiple benefits of sustainable agricultural technologies should be promoted. Exchanging information and providing technical advice on improving input efficiency, Agril. productivity and resilience of agriculture at local and regional scales should be considered.

17. Possible sources of technical and funding supports should be identified for promoting climate-resilient adaptation technologies.

18. Specific attention should be given for improving agricultural extension services by collaborating with private & public sectors as well as NGOs.

19. Media should play crucial role in promoting the adaptation and mitigation technologies. Dedicated TV channels in vernacular languages should be initiated in different states for region-specific recommendations.

20. The women farmers are going to be mostly affected by the adverse impacts of climate change. Climate change adaptation and mitigation technologies, therefore, should take into account the gender-specificity and be women-farmers' friendly.